

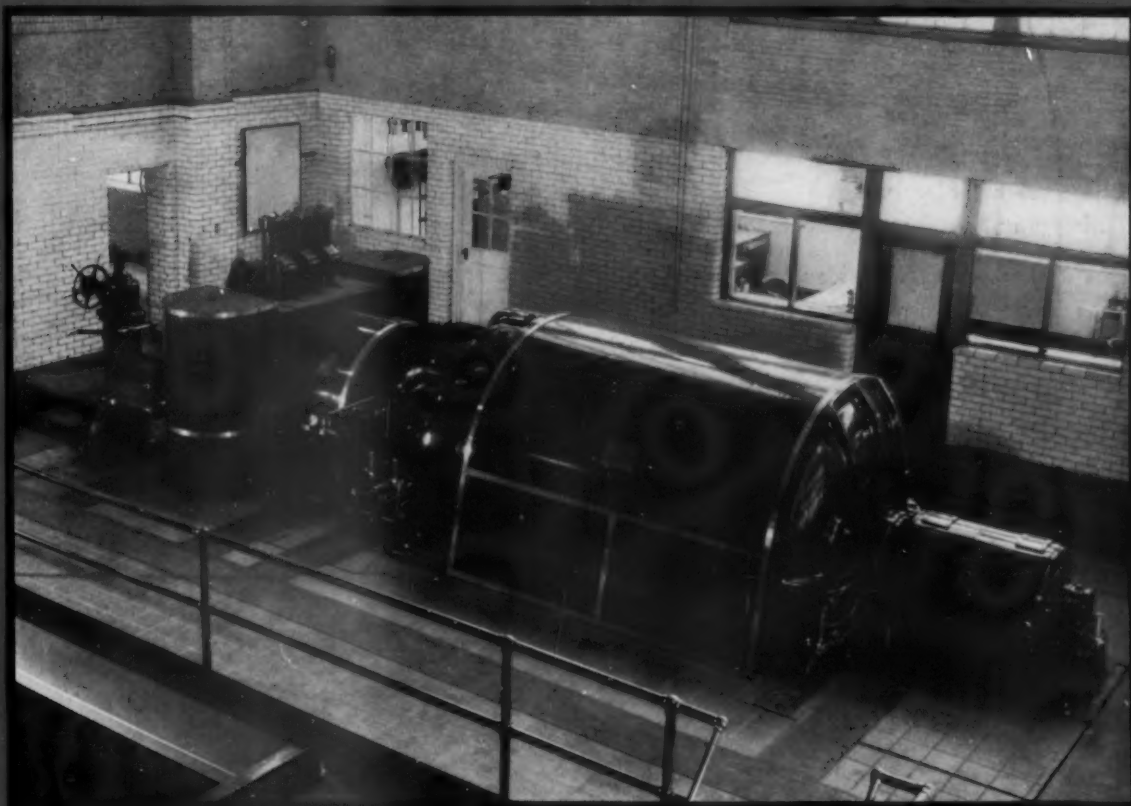
# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

6, No. 8

FEBRUARY, 1935

25c a copy



High-pressure turbine at Akron plant of Firestone Tire and Rubber Company operating at 1250 lb pressure, 750 F and exhausting to evaporators at 235 lb

**1400-lb Installation at the Firestone  
Tire and Rubber Company**

**Fusion Temperature of Coal Ash  
as Related to Composition**

# MODERN STEAM PLANT EQUIPMENT

## Raymond Impact Mill

*Design CL*

*No. 9 of a series presenting design and operating features of C-E products*

### FEATURES

**Feeder** . . . Has variable speed and is easily accessible. May be separate or mounted on the mill. Star roll type.

**Swinging Hammers** . . . are not subject to damage by foreign matter which may pass through feeder. Manganese steel composition.

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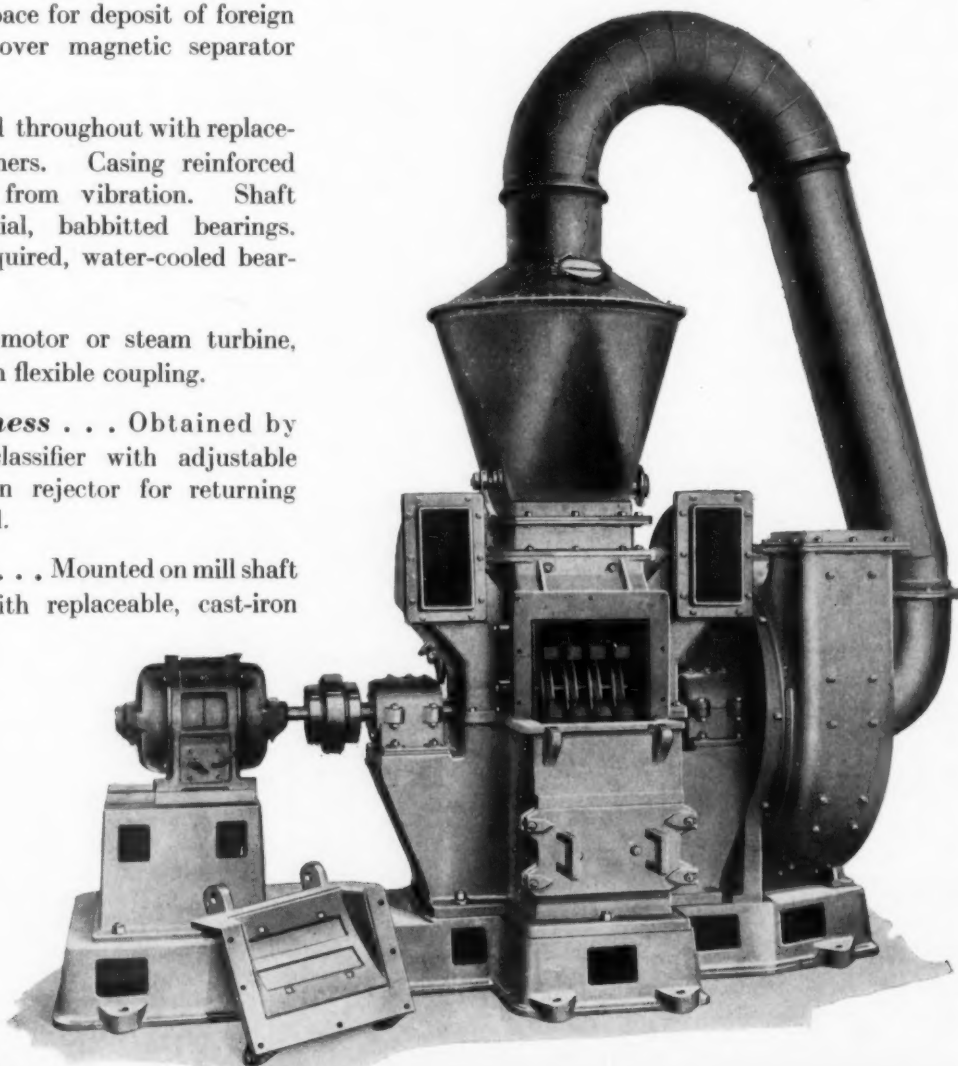
**Regulation of Fineness** . . . Obtained by means of double cone classifier with adjustable sleeve. Positively driven rejector for returning coarse particles to the mill.

**Integral Exhauster** . . . Mounted on mill shaft and lined throughout with replaceable, cast-iron liners.

**Drying of Wet Coal** . . . Accomplished by use of preheated air in the mill.

**Easy Operation** . . . Assured by controls within easy reach and adapted to automatic regulation.

*View of mill with  
swinging door removed  
to show hammers*



## COMBUSTION ENGINEERING COMPANY, INC

200 Madison Avenue, New York, N. Y. . . . Canadian Associates, Combustion Engineering Corporation, Ltd., Montreal  
MANUFACTURING DIVISIONS: The Hedges-Walsh-Weidner Company, Chattanooga, Tenn.; Heine Boiler Company, St. Louis, Mo.; Coshoccon Iron Company, Monongahela, Pa.; Raymond Brothers Impact Pulverizer Company, Chicago, Ill.

A-216

# COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIX

NUMBER EIGHT

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FOR FEBRUARY 1935

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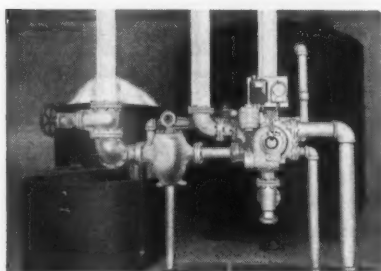
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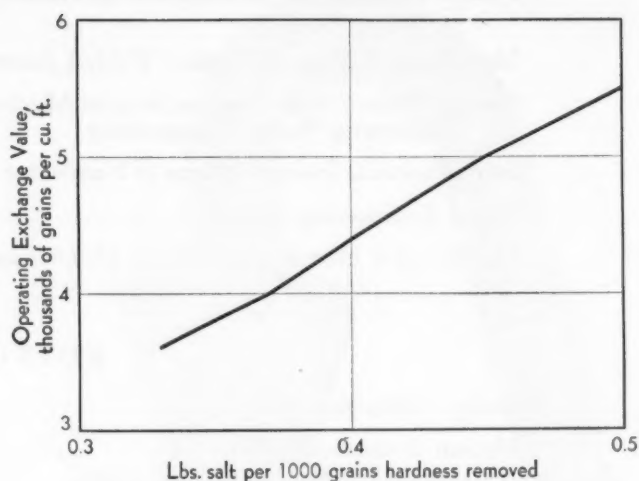
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*Water Treating Equipment*

February 1935—COMBUSTION



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# EDITORIAL

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## Dollar Efficiency

Writing in a recent issue of *Electrical World* on ways to reduce initial power plant costs, Frank S. Clark, of Stone & Webster, says: "There has been a tendency in the past on the part of both company and consulting engineers to request complete performance data and proposals on numerous types and sizes of equipment for a number of different operating conditions where, possibly, a more careful analysis of the situation would have reduced the number of studies to be made."

Mr. Clark's observations are most timely and reflect a situation that still persists. Obviously, the explanation is to be found in the engineer's desire to arrive at that combination which best suits his particular conditions. For this he cannot be criticized, but it might be well to bear in mind that operating conditions are seldom static. They are often dictated by factors impossible to anticipate at the time the plant is laid out and later beyond the control of the operating engineer. In fact, few plants operate for long, if at all, under the precise conditions assumed when they are designed.

For this reason the plant that is designed along advanced yet well-proved lines for the particular industry served will, in the long run, usually show the better dollar efficiency, all things considered.

## Motion Picture Studies in the Field of Power

The National Advisory Committee for Aeronautics has been investigating what goes on inside the cylinder of an internal-combustion engine, especially the diesel, by means of the very high-speed motion picture camera. In this way the speed of normal vision is increased over two hundred times. By slowing down the camera when throwing the picture on the screen it is possible to study carefully every phase of the ignition cycle. The pictures are taken through two one-inch thick plates of special heat resistant lens glass set in the walls of the combustion chamber.

It would seem that this method of investigation might be applicable to other forms of power generation in which there are still some things to be learned, particularly in the combustion of fuels for steam generation.

Numerous studies have been made of what goes on

within a boiler furnace for which purpose gas sampling, pyrometer readings, draft measurements, etc. have been employed as well as visual inspection. By interpreting these readings much evidence has been secured in support of certain theories concerning combustion. Notwithstanding these researches, there is not complete accord on some points, especially as concerns the combustion of pulverized fuel.

Ordinary motion pictures of furnace operation have been taken in the past, despite difficulties incident to the high sensible and radiant heat; but this was before the perfection of the ultra high-speed camera. Just as it is now possible to study the behavior of the fuel spray nozzles in the diesel it should be possible by the same means to study burner action, turbulence, stratification, etc., in a pulverized fuel furnace, with a view to improving designs and exceeding the present very creditable performance of such equipment.

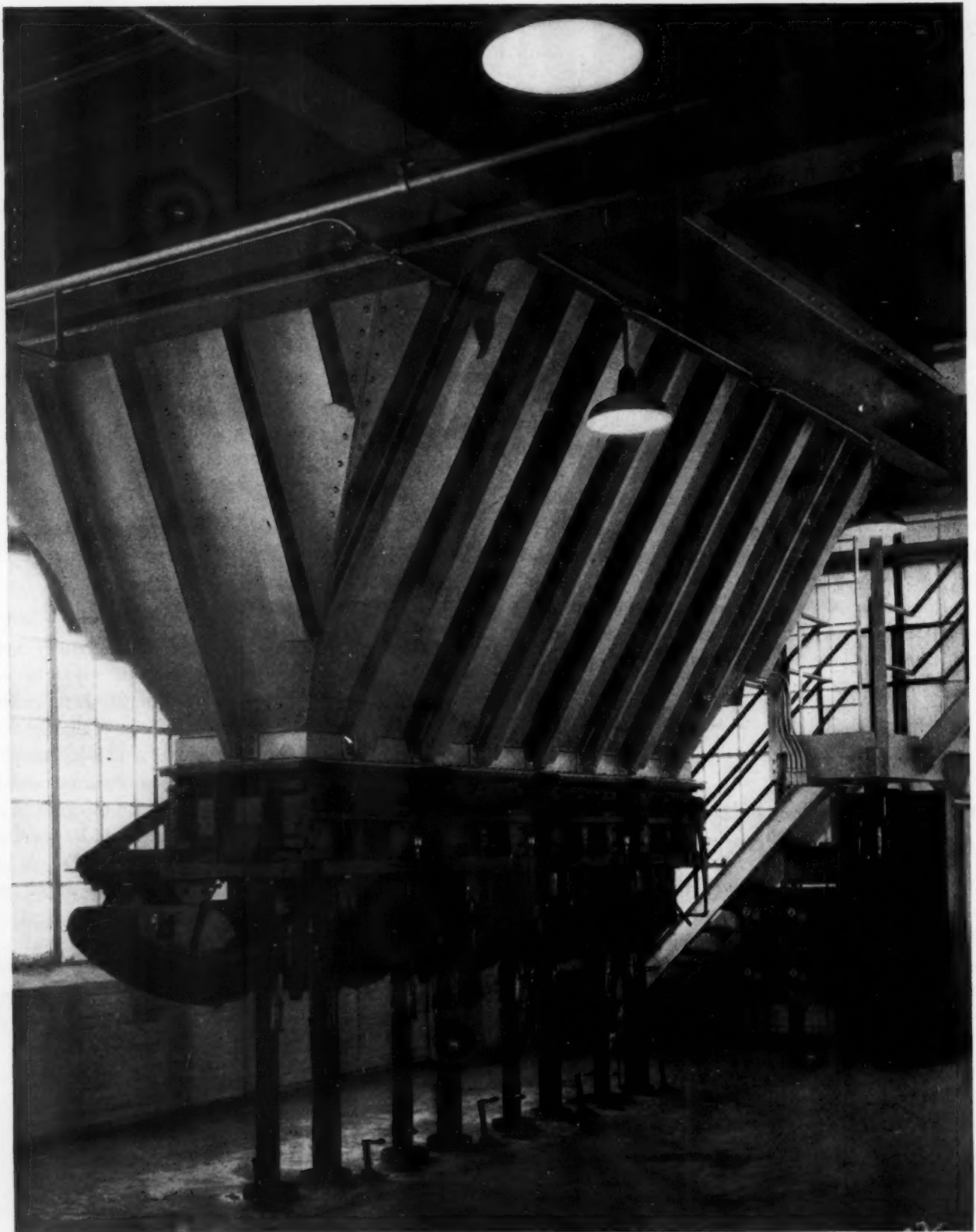
## Holding Companies

Speaking of holding companies in the utility field, David Lawrence, the well known columnist says: "Within the last few days there have been signs of recognition by the Administration of the deflationary character of its policy on holding companies . . . This deflation is preventing the reemployment of persons who would be put to work if the funds so much needed in order to replace worn-out or obsolete equipment could be obtained through refinancing operations."

This statement from Mr. Lawrence, whose opportunities for close observation of trends and policies at the National Capital are exceptional, is re-assuring and indicates that, while the Sword of Damocles still hangs over the industry as a result of the past actions of certain black sheep, the path may be cleared for constructive and legitimate refinancing to enable the industry to put into effect some of its plans for meeting most economically the steadily increasing load.

Whatever action that Congress may take, if any, concerning the status of holding companies in the utility field, it should not lose sight of the very effective engineering set-up that now exists in many systems whereby the smaller companies receive the benefit of the advice and experience incident to group supervision. To disturb this would in many cases be a step backward.

# 1400-lb Installation



Pulverized coal bin and feeders serving Firestone boiler

# at the Firestone Tire and Rubber Company

WHEN it became apparent last Spring that the Akron plant of the Firestone Tire and Rubber Company would require increased power facilities, a study of the steam demands for power and process showed these to be about equal if condensing turbines were employed. It was apparent that the installation of a large high-pressure boiler and a back-pressure turbine would best suit the conditions. Further study indicated that the most desirable heat balance could be obtained with 1400 lb per sq in. working pressure, a boiler capable of producing 300,000 lb of steam per hour and a 10,000-kw turbine-generator taking steam at 1250 lb, 750 F and exhausting at 235 lb to evaporators which, in turn, would supply process steam. By thus providing a closed steam circuit for the high-pressure boiler it was believed that the boiler water problem would be simplified and makeup practically eliminated.

As the plans progressed further it was decided to install both a plate-type air heater and an economizer, the latter, placed ahead of the former, receiving the evaporator condensate at 380 F and heating it to 472 F. Inasmuch as a storage system of pulverized coal firing was already installed in the plant, with ample capacity to supply the new unit which displaced four old boilers, it was unnecessary to install additional pulverizing capacity. However, a 90-ton pulverized coal bin for the new unit was provided, as well as four type R duplex feeders and four 8-in. duplex tangential burners. A slagging type of furnace was selected.

The boiler, which has recently gone into operation, has some unusual features. Although not the largest 1400 lb boiler, it has the distinction of being the first large high-pressure boiler to have fusion welded drums. The arrangement of the furnace walls is of special interest and the inclusion of a plenum chamber, air heater, economizer and fuel piping within the casing presents a compact and exceptionally neat arrangement.

It is of the C-E cross-drum, sectional-header, three-pass type, 34 tubes wide, having a main steam drum 54 in. diameter, 23 ft long and 4 in. thick. Immediately below the main drum is an auxiliary drum of the same length and 36 in. diameter, which increases the reserve water-storage capacity so that the boiler will operate at full load for 2.7 minutes with the feed shut off. The drums are fabricated from 70,000 lb T. S. steel and because of the thickness of the plate it became necessary to develop a new technique in X-ray examination of the fusion welding.

The furnace which is of the slagging type, designed to burn coal of 2100-2200 F fusing temperature, is completely water cooled with 3 $\frac{1}{4}$  in. plain tubes on the four

The 1400-lb pressure 300,000 lb per hr steam generating unit which recently went into operation at the Akron plant of the Firestone Tire and Rubber Company supplies a 10,000-kw turbine-generator that exhausts to evaporators which, in turn, supply steam for process. Thus a closed steam circuit is provided. Pulverized coal is burned in a slagging furnace and the boiler has several novel features which are here described. Furthermore, the main steam drum is the largest high-pressure drum ever made by fusion welding process. For much of the information contained in this description and for approval of its publication we are indebted to W. K. Adkins, power engineer of the Firestone Tire and Rubber Company.

walls and fin tubes on the bottom, aggregating a total of 7584 sq ft of surface. The water walls are backed by 2 $\frac{1}{2}$ -3 in. of insulating brick over which 3 in. of rock wool is applied and covered with No. 10 gage steel casing. Firing is from all four corners by eight tangential burners and at full load the anticipated heat release is 24,100 Btu per cu ft of furnace volume per hour.



Looking up into the furnace

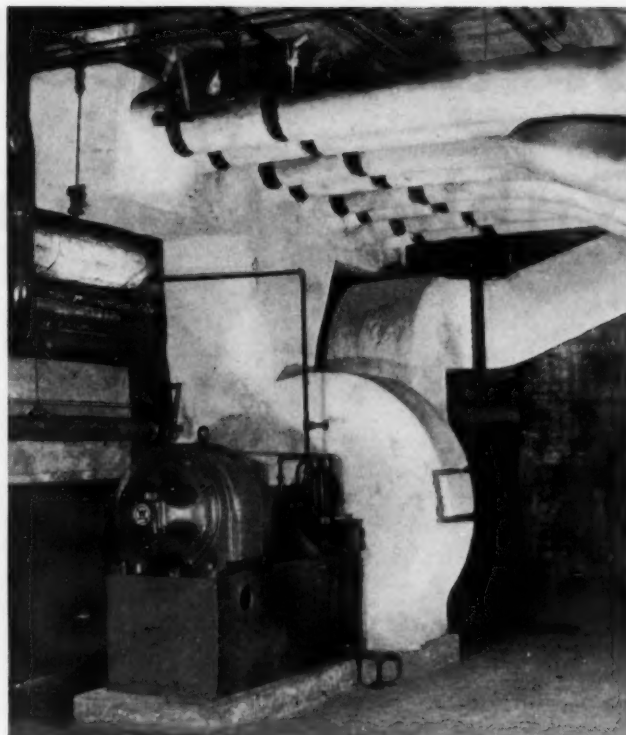


As may be seen by reference to the cross-section, the furnace side walls are carried by headers on either side from which extend upward the boiler side wall risers. The front and rear furnace walls are carried by headers tied in, respectively, with the front boiler header and the two bottom rows of boiler tubes. The downcomers from the rear boiler header feed a header at the rear and bottom of the furnace, and out of this last header, and below the I-beams supporting the bottom fin tubes, extend horizontal tubes which turn at right angles and rise to form the furnace side walls. The bottom fin tubes, which extend from front to rear across the furnace, terminate in their own headers, one of which is supplied by the rear wall header. The I-beams are tied into the steelwork and carry the weight of the furnace contents, whereas the furnace walls and the boiler walls are free to expand upward and downward from the central suspension independent of the boiler proper and of the furnace bottom. For initial operation a refractory material was applied to the furnace bottom but in regular operation the fin tubes chill the slag so that it forms its own seal. The slag when tapped passes to a disintegrating chamber and is then pumped to a de-watering tank from which it is removed periodically.

The heating surface comprising the steam generating unit is made up as follows:

	Sq ft	Per cent
Boiler heating surface	11,793	21.6
Water walls and bottom	7,584	14.4
Economizer	8,110	14.7
Air heater	23,100	42.0
Superheater	4,000	7.3
Total	54,587	100.0

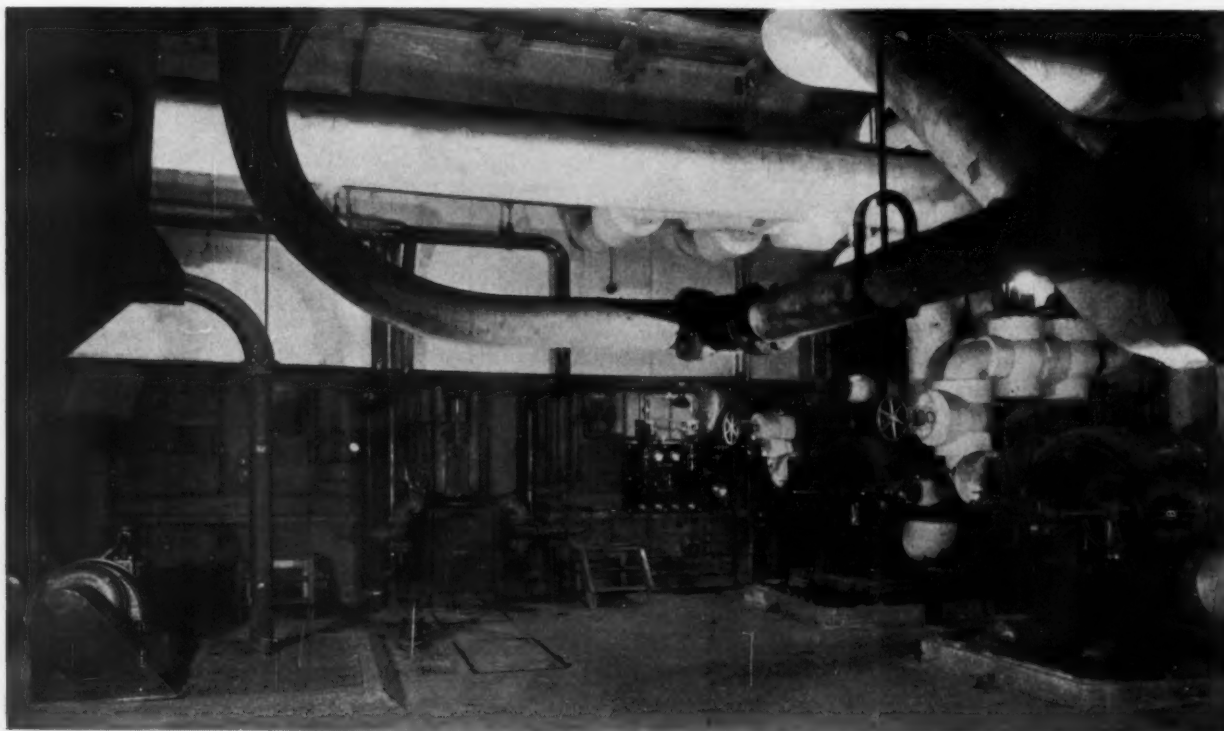
The air heater is capable of raising 313,000 lb of air per hour from 100 F to 440 F with gas entering at 687 F and leaving at 410 F. The forced-draft fan, located on the operating floor above the induced-draft fan which is in the basement, forces the air for combustion through the air heater and into the plenum chamber from which



Primary air fan

ducts, integral with the casing and containing the fuel feed pipes, carry it to the primary air fan and around the burners, as secondary air. Both the primary and the secondary air are delivered to the furnace at the same temperature, namely about 440 F.

The induced-draft fan has a capacity of 183,000 cfm at 410 F against a static pressure of 11½ in. of water. The forced-draft fan has a capacity of 103,000 cfm at 100 F against a static pressure of 10 in. of water and the primary air fan has a capacity of 21,000 cfm at 440 F against a



Boiler feed pump turbines (right) and slag disintegrating equipment (center)

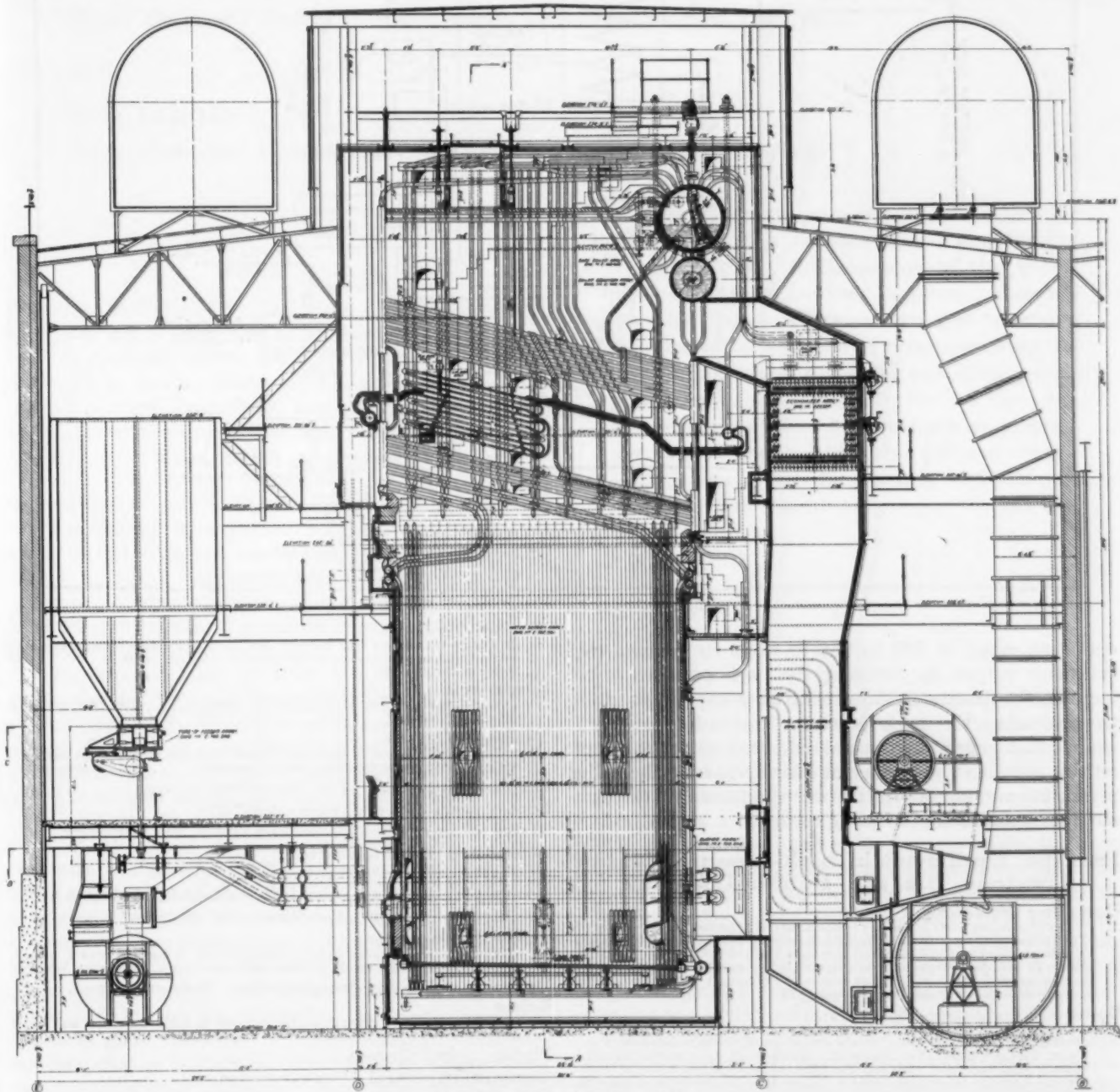
static pressure of 15 in. of water. Constant-speed drives were selected inasmuch as the unit is designed for base load operation.

A combustion control system is provided which regulates the position of the dampers on the forced- and induced-draft fans and the speed of the feeder motors.

Feedwater is supplied by two 850 gpm seven-stage turbine-driven pumps, one of which is a spare. These pumps have triple labyrinth stuffing boxes at both ends and are provided with cooling facilities to preserve the

The turbines driving the feed pumps are supplied with steam from the 225 lb station header. They are equipped with both overspeed and pressure control governors and a quick opening valve is installed in the steam line, ahead of the governors, which opens and immediately starts the spare pump if the pressure in the feed line drops below a pre-determined point.

There are five evaporators which, when operating in parallel and supplied with 269,000 lb of steam per hour at 235 lb gage dry and saturated, will produce 260,000

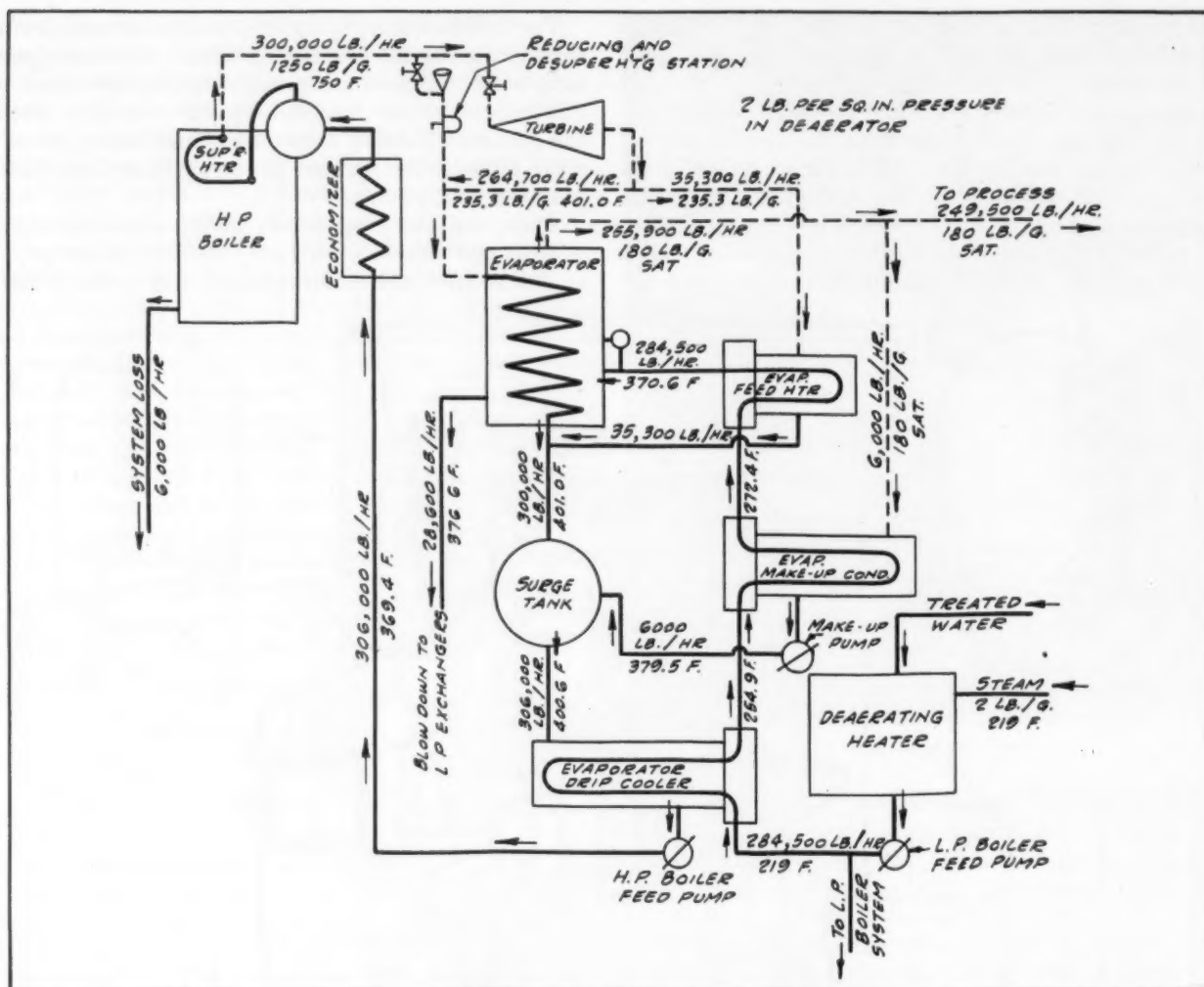


Section through boiler plant

life of the packing and keep leakage to a minimum. The balancing line, which normally returns to the suction, has been piped to the surge tank which allows some flow through the pump at shut-off. Another advantage of this is that the water circulates through the idle pump keeping it warm and ready for use. The delivery head on the pumps is 3604 ft, not including the 235 lb on the suction.

lb of steam at 180 lb gage, when supplied with 370 F feedwater. This performance is based on feedwater containing not more than 22 gr per gallon total impurities and a maximum concentration in the shells not exceeding 250 gr per gal. A continuous blow-down system, which salvages the flash steam at 2 lb and the heat of the liquid above 100 F is installed to maintain this concentration.

The main turbine has a back-pressure governor with an



Heat balance for initial operation

operating range of 220 to 265 lb so as to increase the generator output by reducing the back pressure or to increase the process steam generated in the evaporators by increasing the back pressure. In order to guard against lack of process steam should the turbine be out of service, provision has been made for by-passing the high-pressure steam around the turbine and passing it through a reducing and desuperheating station.

### Principal Equipment in High-Pressure Plant of Firestone Tire and Rubber Company

#### Operating Conditions

Boiler pressure 1400 lb; steam temperature at superheater outlet 760 F. Pressure at turbine 1250 lb. Rated capacity of boiler 300,000 lb per hr. Steam supplied to 10,000-kw back-pressure turbine exhausting to evaporators at 235 lb. Process steam supplied by evaporators and closed circuit employed for high-pressure steam. Pulverized coal firing, with storage system. Slagging furnace employed.

#### Boiler

One sectional-header, cross-drum type with both main and auxiliary drums, both fusion welded. Main steam drum 54 in. diameter, 4 in. plate; auxiliary drum 36 in. diameter. Completely water-cooled slagging furnace with bare tube walls and fine tube bottom. Type R duplex feeders and Lopulco tangential burners. Plate type air heater and integral loop economizer. . . . Combustion Engineering Company, Inc.

#### Superheater

Elesco multiple loop, single-pass interdeck type. . . . The Superheater Company.

#### Draft System

One 90-in., 21,000 cfm, at 440 F. primary air fan; one 103,000 cfm, at 100 F forced-draft fan; one 183,000 cfm, at 410 F induced-draft fan. . . . Buffalo Forge Company. Constant-speed, 2300-volt Westinghouse motors.

#### Boiler feed and make-up pumps

Two seven-stage 850 gpm at 370 F against total head of 3804 ft at 3550 rpm, driven by Terry turbines. . . . Ingersoll-Rand Company. Two 1 1/2 in. single-stage pumps 50 gpm at 380 F against 345 ft head, driven by Allis-Chalmers motors. . . . Ingersoll-Rand Company.

#### Evaporator equipment

Five single-effect coil-type evaporators, each of 52,200 lb per hr capacity at 180 lb gage for process steam; one horizontal, floating-head, 289,500

lb per hr evaporator feed heater; one 310,000 lb per hr evaporator drip cooler; and one horizontal 10,000 lb per hr makeup condenser. . . . Foster Wheeler Corporation.

#### Surge tank

One Class I welded tank for 275 lb pressure. . . . The Hedges-Walsh-Weidner Company.

#### Deaerating heater

One 400,000 lb per hr steel shell heater with 500 cu ft storage capacity; welded construction for 30 lb working pressure. . . . Elliott Company.

#### Distilled water tank

Biggs Boiler Works Company.

#### Soot blowers

Diamond "Valve-in-head" type.

#### Water columns

Two Diamond loose window, 21 1/2 in. visibility.

#### Safety stop and check valves

Drum—Three 3-in. Crosby type H.N.

Superheater—One 3-in. Crosby type H.N.A.

Feed lines—Two 4-in. Edward stop and two 4-in. check valves.

#### Ash disposal system

Allen-Sherman-Hoff "Hydrojet."

#### Feedwater regulator

Drum level controller quick opening valves in turbine steam supply, pump governors and excess pressure regulator. . . . Swartwout Company.

#### Reducing valves and desuperheater

Swartwout Company.

#### Valves

Globe checks and gates from 150 to 1500 lb for both steam and boiler feed. . . . Wm. Powell Company.

#### Piping

Grinnell Company.

#### Combustion control

Hagan Corporation.

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Bailey Meter Company.

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Crosby Steam Gage & Valve Company.

#### Insulation

Keasbey & Mattison Company.

#### Duct work

Combustion Engineering Company, Inc.

#### Turbine-generator

One 10,000-kw, 3600 rpm back-pressure turbine driving 3-phase, 60-cycle, 11,000-volt, generator. Steam conditions, 1250 lb gage, 750 F (176 deg superheat) and 236 lb gage back pressure. . . . General Electric Company. Water rates at various loads:

Kw	Water rate	Btu per lb exhaust	O. & Superheat exhaust
4,000	36.95	1241.9	63
7,000	30.45	1224.5	36
10,000	28.00	1215.2	21
10,870	27.60	1213.8	19



# Fusion Temperature of Coal Ash as Related to Composition

By A. H. MOODY

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and

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FUNDAMENTALLY the fusion temperature of coal ash is a function of its chemical and physical composition. It is the purpose of the writers to show: First, that a relationship exists; second, what relationship exists; and third, how gas composition may affect the relationship of the fusion temperature to the chemical composition of coal ash.

Fusion temperature as defined by the A.S.T.M. method of testing fusibility of coal ash (1)\* does not refer to a melting temperature, but to a temperature at which an ash cone has reached an overall viscosity low enough to permit the cone to exhibit deformation. The mechanics of this phenomenon are a bit complex, but must be understood, if a comprehensive understanding of what takes place is to be had.

Tammann and Mehl (2) state that: "No theoretical qualitative distinction exists between the solid and liquid state." Maxwell (3) defines solids as: "Bodies which possess rigidity or offer resistance to deformation by mechanical force." This characteristic however is found to a lesser degree in even crystalline solids. The term solid may be reserved for crystalline substances, or modified by use of the term crystalline solid. Taylor (4) states: "The majority of substances can exist in solid forms which are bounded by plane surfaces so oriented to one another that the whole possesses some degree of symmetry. A substance in this state is said to be crystalline and the state is called the crystalline state of aggregation. All other solid bodies are classed as amorphous and are to be regarded as nothing other than liquids of great viscosity." Many substances, however, are composed of crystals too small to be recognized even with the aid of the microscope. Amorphous solids gradually lose their shape on heating and slowly assume true liquid characteristics. Crystalline solids exhibit an abrupt change at their melting point on being heated, and require a definite amount of heat to effect the transition—the heat of fusion.

The abrupt change from the crystalline solid state to the liquid state is known as melting. The melting temperature is defined by Wilson (5) as "The constant temperature at which the liquid and crystalline phases of

The chemical analysis of coal ash has been found to be related to the fusion temperature. A discussion of the theoretical factors involved is given. Experimental data has been plotted so that the fusion temperatures of mixtures may be predicted. The effect of reducing gases has been shown in relation to composition of the ash. Much knowledge may be gained concerning the general characteristics of ash by a study of their relation to the chemical composition of the ash.

the same composition are in equilibrium with each other." This does not mean that the liquid must be of a low viscosity, for what is known as an amorphous solid may result, and an appreciable degree of fluidity may not be reached for another hundred degrees.

Coal ash is a mixture of several substances, most of which are crystalline, and as such on being heated does not exhibit the same characteristics as a pure amorphous or crystalline solid. Its behavior is determined by the eutectics and the solubilities of its components, as well as the viscosities of various liquid compositions which are formed. A knowledge of what is meant by a simple congruent melting temperature is necessary and a prerequisite to understanding eutectics and solubilities.

When one compound is added in increasing amounts to another compound, the temperature at which the last of the solid material goes into solution is successively lowered, until a composition is reached which gives the lowest temperature in the system. This is called the eutectic composition. At this temperature both compounds in the solid phase are in equilibrium with each other.

On heating a mixture of any composition between the eutectic composition and one of the two components, the maximum amount of the eutectic composition possible will melt. On further heating, more of the component which is in excess will be dissolved as its melting tempera-

\* Numbers in parentheses refer to bibliography at the end of this article.

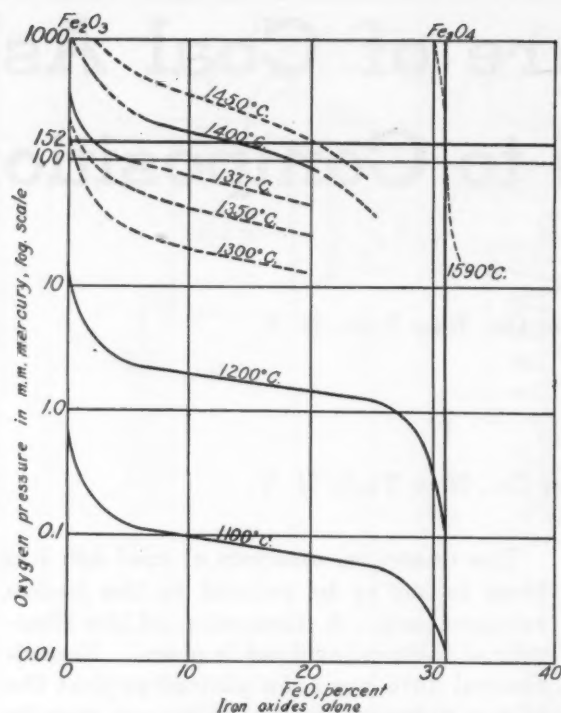


Fig. 1—Dissociation pressure and composition (Hostetter, Sosman and Roberts, Jour. Am. Ceramic Soc., v. 4, p. 931, 1921)

ture is approached. That is, the solubility of a component which is in excess is increased with a rise in temperature. The composition of the saturated liquid may be plotted against temperature to give the saturation or solubility curve of the system.

The fusion point of a mixture, as defined by the A.S.T.M., would be a temperature at which enough of the component (the one in excess) had been dissolved in the eutectic composition to permit deformation. This fusion point will usually lie between the eutectic and final saturation temperature, the distance above the eutectic temperature varying inversely with the amount of eutectic composition present, and directly with the viscosity of the fluid formed.

The two components may react with each other to form one or more compounds in some definite molecular ratio. There will then be two or more eutectics formed, each of which may be considered as constituting a separate system. An illustration taken from Rankin and Wright (6) states: "Let us say that in studying a two component system we find that as increasing amounts of B are added to A the melting temperature is lowered until a point is reached where the curve rises again. After rising to the composition AB it again goes down to another low and then up to the composition of component B. In this illustration there are two simple binary eutectics, namely A-AB and AB-B. There may be more than two. The concentration temperature diagram for the lime-alumina system has four such eutectics."

Up to the present we have discussed systems of only two components. Systems of three components follow the same general behavior of the two component systems. A description of the curves used for graphic representation of three component systems is taken from Johnson (7): "They are based on the fact that in an equilateral triangle the sum of the perpendicular distances of any interior point from the three sides is a constant, irrespective of the location of the point, and therefore the

composition of any substance made up of three components may be graphically represented by the position of a point whose distances from the respective sides are represented by the percentages of the corresponding components. Each angle of the triangle represents one component unmixed with anything else. Any point on one side represents a composition consisting solely of the two materials represented by the two ends of that side without any of the third component, and the percentage of this third component increases in proportion to the perpendicular distance from this line. This enables us to plot the proportions of the three fundamental variables on one plane, and therefore to plot any independent function of all these upon ordinates normal to that plane (vertical). The surface passing through the tops of these ordinates furnishes a graphic representation of the variation of the independent variable with changes in the composition of the material under consideration." This surface may be projected to the base in the form of contour lines as is done on topographical maps.

We may study the behavior of the three two component systems which make up the boundary of the three component diagram and learn what condition any two component system will be in at a definite temperature and composition. A good generalization of how the three component system behaves inside the triangle is taken from Bancroft (8): "A theorem by Van Rijon Van Alkemade serves as a very effective guide in regard to temperature changes in the interior of the triangle. If two points in the triangle which correspond to the composition of two solid phases be connected by a line, the temperature at which these same two phases can be in equilibrium with solution and vapor rises as the boundary curve approaches this line, becoming a maximum at the intersection, though the boundary curve often ceases to be stable before this point is reached. When the two solid phases are the two components, the line connecting their compositions is one side of the triangle. It is, therefore, clear that the temperature must always rise in passing along a boundary curve to the side of the triangle if the theorem of Van Alkemade be right." The boundary lines referred to by Bancroft are lines starting

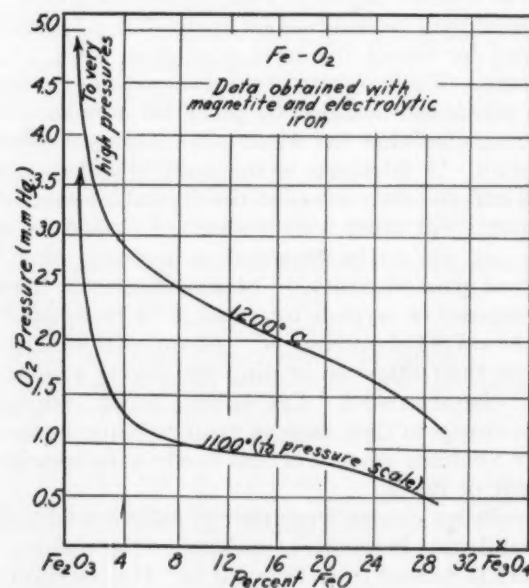


Fig. 2—Iron oxides alone. Oxygen pressure and per cent reduction Int. Critical Tables



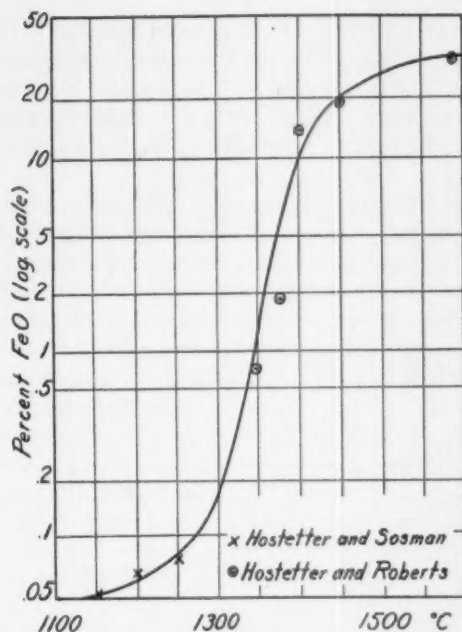


Fig. 3—Iron oxides alone. Composition and temperature for charges heated in air (152 mm isobars) (Hostetter and Roberts, Jour. Am. Ceramic Soc., v. 4, p. 932, 1921)

at the eutectics of the two component systems represented by the sides of the triangle and proceeding to the interior where it meets a three component eutectic. The saturation temperature reaching a minimum at the three component eutectic. As in the two component system, the three component system may have more than one eutectic due to compound formation.

Equilibrium or saturation in a four component system is expressible graphically in a regular tetrahedron. The isotherms, or contour lines, in the three component system becoming isothermal surfaces. This figure is very complex, and can only be shown through complicated methods of projection, but we may examine cross-sections of the tetrahedron taken parallel to one of its faces to determine how three of the variables behave when a constant amount of the fourth variable is present. The section may also be taken in such a way as to show the relation of an independent variable to four dependent variables when two or more bear a constant ratio to each other.

The independent variable may be any property, which mixtures of the components exhibit, that varies with composition such as: density, specific heat, saturation temperature, or the A.S.T.M. initial deformation, and softening temperature. The last two properties are the ones in which we are interested. To be specific, the initial deformation temperature is the temperature at which a cone made of ash shows the first perceptible sign of fusion; the softening temperature is the temperature at which the cone loses its shape completely and becomes hemispherical. The temperature at which these changes will take place is controlled by the composition of the material tested. The process of fusion consists of the formation of the greatest amount of liquid of eutectic composition possible, and the subsequent dissolving of the more refractory component (any component or components in excess) as its solubility in the liquid is increased by the rise in temperature. The liquid assumes the role of lubricant, as well as that of solvent, and allows solid particles to slide and exhibit deforma-

tion. The viscosity of the liquid is dependent upon its composition and varies widely. The effect of this difference is shown in the softening interval, i.e., the difference between the initial deformation and the softening temperatures. The size of the particles also affects the softening interval by increasing the time necessary for them to go into a viscous solution which approaches saturation at the interface between the solid particle and the liquid. However, for mixtures which are uniform in particle size range, it seems reasonable to assume that the softening interval is entirely dependent upon the viscosity of the liquid.

The material thus far presented has consisted of a discussion of eutectics complimented by its application to the phenomena observed in fusibility tests of coal ash. It has embraced the orthodox method of plotting characteristics dependent upon variations of composition in systems with as many as four variables of composition, or components. One of the components, or variables of composition, of coal ash is iron oxide, which may be any one of three chemical compounds, or a mixture of two compounds in the ash as fusion takes place. That is, it could, and does constitute three variables of composition and would, if treated as such, occupy three of the four vertices in a four component diagram. The three oxides of iron are intraconvertible. The conversion from one form to another is possible in coal ash regardless of the ratio of the other constituents to the iron oxide, or of their ratio to each other. Therefore, since the state of oxidation of the iron is not primarily a function of the other constituents, the state of oxidation may be considered as constant for the purpose of plotting. In the furnace it is constantly changing with changes of the temperature and the composition of the gases which surround it. For the sake of simplicity in plotting, the assumption will be made that the conditions vary and correspond with temperature. In other words, we are assuming that temperature is the only independent variable. This assumption is valid, because the procedure specifies roughly the conditions within the furnace for different temperatures. Temperature therefore includes the effect of the rate of heating, the composition of the gases and the temperature at which changes are observed. The validity of the above assumption, in no way nullifies the importance of the actual state of oxidation of the iron oxide in the furnace, or boiler and a dis-

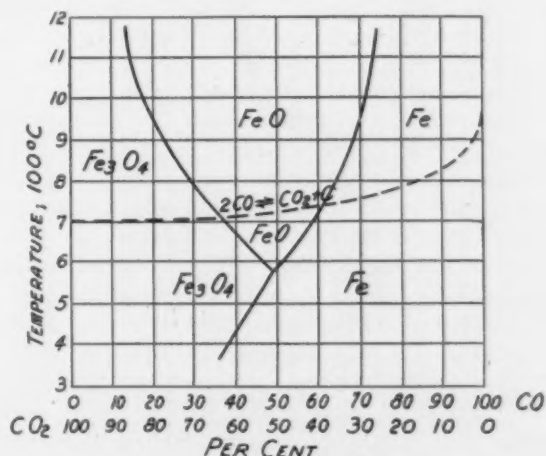


Fig. 4—Chemical equilibrium between iron, carbon and oxygen (Eastman, Jour. Am. Ceramic Soc., v. 4, p. 927-938, 1921)



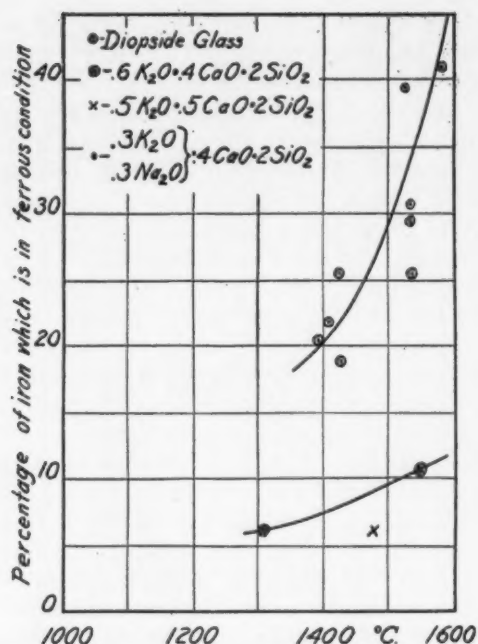


Fig. 5—Iron oxide dissolved in glass, composition and temperature for charges heated in air (152 mm isobar) (Hostetter and Roberts, Jour. Am. Ceramic Soc., v. 4, p. 934, 1921)

cussion of the factors influencing its oxidation, or reduction, is pertinent.

When any of the three oxides of iron,  $\text{Fe}_2\text{O}_3$ ,  $\text{Fe}_3\text{O}_4$ ,  $\text{FeO}$ , are heated in vacuo, oxygen is given off until a certain oxygen pressure is attained. This pressure of oxygen in contact with the oxide varies with the temperature for all three of the oxides. As the oxygen is evolved an equivalent amount of the next lower oxide or of metallic iron is formed. Therefore, for any oxygen pressure one and only one of the oxides can be in equilibrium at a given temperature with the vapor. This statement is true as long as no fusion of the materials has taken place. After fusion, a solution is formed which gives any pressure between the pressures of the two constituents corresponding to the temperature at which the solution is held. Fig. 1, taken from an article by Hostetter and Roberts (9), and Fig. 2, taken from the International Critical Tables (10), show the characteristic shape of pressure-composition curves for several temperatures. The solid lines are based on data obtained and the dotted lines show the probable shape of other isotherms.

Ferric oxide when heated in air (152 mm partial pressure of oxygen) to 1100 C (2012 F) must according to the curve of Fig. 3 begin to lose oxygen, and if no solid solution occurred could decompose completely to  $\text{Fe}_3\text{O}_4$ , with no further rise in temperature. If ferric oxide is heated to 1590 C (2894 F) where melting takes place there is a complete conversion to magnetite. This oxygen loss is reabsorbed if the sample is cooled slowly, thus indicating that the reaction is reversible.

Hostetter and Roberts (9) state: "The formation of 'ferrous oxide' (magnetite may be considered 31.1 per cent  $\text{FeO}$ , 69.9 per cent  $\text{Fe}_2\text{O}_3$ ) under these conditions—by dissociation—is to be carefully distinguished from the reduction of ferric oxide by such constituents of furnace gases as carbon monoxide and hydrocarbons. These gases not only dilute the oxygen, thereby lowering its partial pressure, but they remove oxygen from the already reduced ferric oxide and combine with it chemically, thus increasing the amount of ferrous oxide. The

formation of ferrous oxide by dissociation in the first case takes place under what are ordinarily considered to be oxidizing conditions. In fact, it has been shown that ferric oxide loses weight with attendant formation of ferrous oxide in one atmosphere of oxygen at 1300 C (2372 F)."

Analyses of furnace gases show very small percentages of hydrocarbons. Their effect upon the iron oxide present in ash cones is relatively slight in the presence of the high concentrations of carbon monoxide usually found. The presence of carbon monoxide has a very important influence on the state of oxidation of the iron and a consequent effect on the fusion temperature of coal ash. Fig. 4 taken from Eastman (11) shows the state of oxidation at different temperatures of iron in equilibrium with various mixtures of carbon monoxide and carbon dioxide. The dissociation curve for carbon dioxide is also shown. By use of these curves the degree of oxidation at any temperature may be found if the composition of the gases is known. It is to be noted that with 100 per cent carbon dioxide,  $\text{Fe}_2\text{O}_3$  is not stable at any of the temperatures shown on the curve. This fact is in perfect agreement with the curves of Fig. 1, as with 100 per cent carbon dioxide the  $\text{Fe}_2\text{O}_3$  has no oxygen pressure resistance to overcome in dissociating. This is purely a case of dissociation. The effect would be the same if the carbon dioxide were replaced by any gas which would not enter into a reaction with oxygen such as nitrogen. With increased concentrations of carbon monoxide, and with increased temperature, magnetite ( $\text{Fe}_3\text{O}_4$ ) also becomes unstable, dissociating into ferrous oxide above 600 C (1112 F) and into metallic iron below. The ferrous oxide also dissociates into metallic iron at very high concentrations of carbon monoxide at higher temperatures. Ferrous oxide has the greatest fluxing action of the three oxides upon silicates, that is, it forms the lowest melting eutectics, but metallic iron is insoluble in silicate melts and can have no effect upon them. The complete reduction of iron oxide has the effect of removing the iron from the reaction completely.

In addition to the tendency of iron oxides to dissociate into lower oxides on heating, and the effect of the presence of reductants, there is a third factor which influences

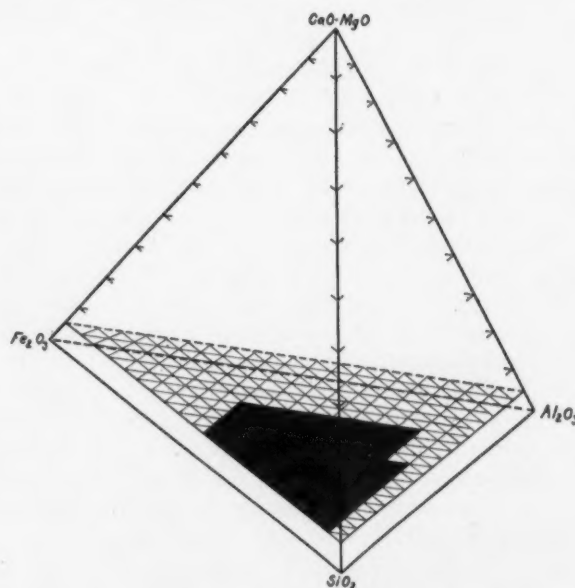


Fig. 6—Four-component diagram showing area investigated

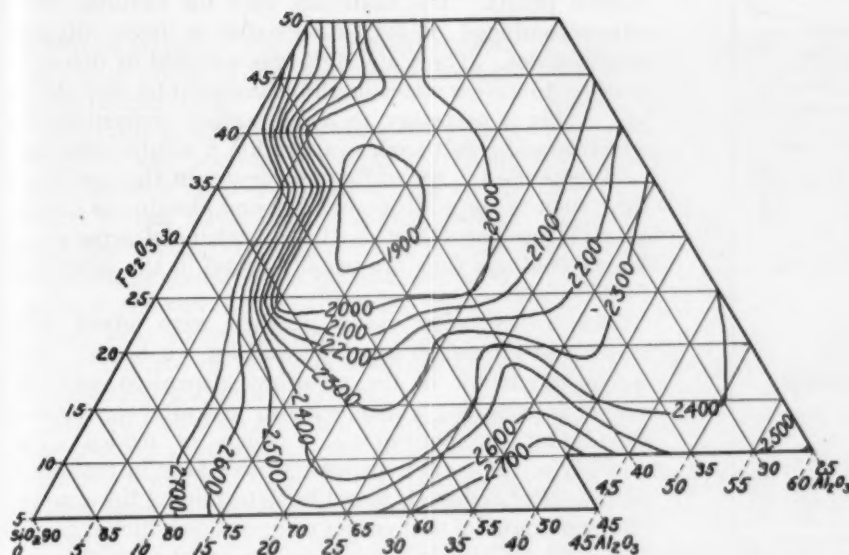


Fig. 7—A.S.T.M. initial deformation isotherms for varying compositions

oxidation or reduction, namely, the composition of the liquid into which the iron oxide may dissolve. The importance of this phase of the problem is questionable, and the literature is almost barren of data concerning it. Hostetter and Roberts (9) performed several experiments upon the effect of the composition of iron bearing glasses on the state of oxidation of the iron oxide dissolved. The results of these experiments are shown graphically by Fig. 5. Hostetter states: "It can also be readily enough shown that ferric oxide dissolved in glass loses oxygen at higher temperatures, even under the oxygen pressure of the air. . . . The actual dissociation in any particular case will depend on the composition of the glass in which the ferric oxide is dissolved. Any variation in composition of the glass will be reflected in the dissociation pressure at a given temperature since, a change either in the number or character of the components, or the concentration in a given system, will necessarily raise or lower the pressure in a manner depending on the characteristics of the system." A comparison of the curves of Fig. 5 with that of Fig. 3 reveals that the per cent of ferric oxide reduced may be increased or decreased for a definite temperature by dissolving it in a glass, or slag, the amount and effect depending upon the composition of the glass or slag. The comparison also reveals that the amount reduced in a particular glass composition may be either more or less than in air for different temperatures. The glass compositions represented are not similar to the general composition of slags formed by coal ash, but do indicate that a change in the dissociation pressures of iron oxide dissolved should be expected.

A consideration of the factors influencing the state of oxidation of the iron oxide in ash is important as it offers an explanation of conflicting results where all conditions are not similar. It also shows the necessity of simulating conditions in the laboratory to those met in practice,

if significant results are to be obtained.

Coal ash is composed of a mixture of clay, silica, iron oxide, calcium oxide, magnesium oxide, etc., usually found in colloidal or amorphous forms. High temperatures tend to eliminate the colloidal phase and to replace it with easily forming silicate glasses. The samples used in fusibility determinations still have the colloidal form present, together with small fragments of crushed quartz and sintered lumps of ferric oxide. The manner in which the constituents are combined varies with the general geology of the coal formation. Coals high in sulphur usually yield a gray or reddish gray ash, which when powdered in a mortar turns bright red, the color of ferric oxide. Coals low in sulphur and high

in calcium, usually yield a brown ash which remains brown on being powdered. These observations lead to the belief that in the former case the iron is combined with the sulphur as pyrite or some iron sulphur mineral, while in the latter case the sulphur is combined as an organic compound and the iron is combined with the silica. This theory is further strengthened by the fact that coals having brown ash fuse at slightly lower temperatures than those giving red or gray ash of the same ultimate analysis. This lowering of the fusion temperature would be expected if some of the elements were combined before fusibility tests were started as the reactions in silicate melts are sluggish, and the temperature of the furnace increases at a rather rapid rate. The temperature difference for ashes having the same chemical analysis, but obviously of different mineral combination, has been observed to be as much as 75 deg F. If two ashes having the same chemical composition, but combined differently are melted, ground, made into cones and the fusibility tested, there is no detectable difference in their softening temperature. This discrepancy must exist in any method of showing the relation of the chemical composition to the fusibility of coal ash. The aluminum oxide

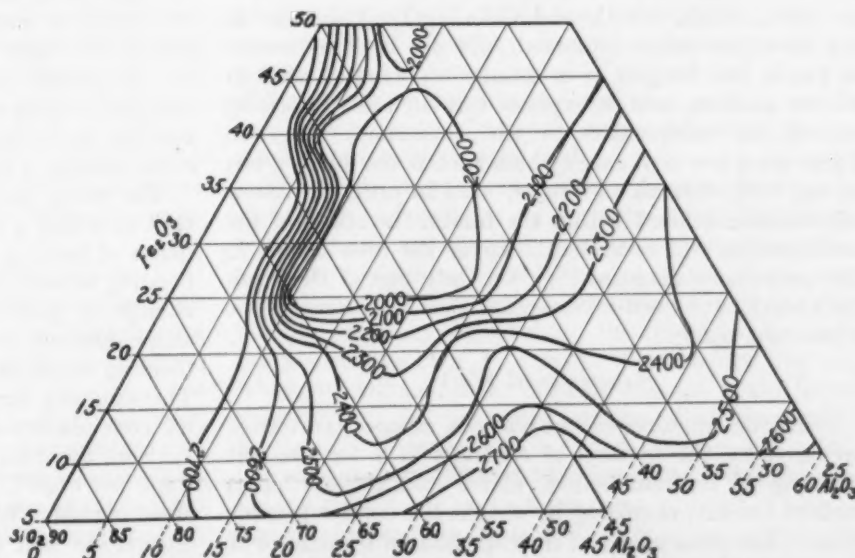


Fig. 8—A.S.T.M. softening isotherms for varying compositions



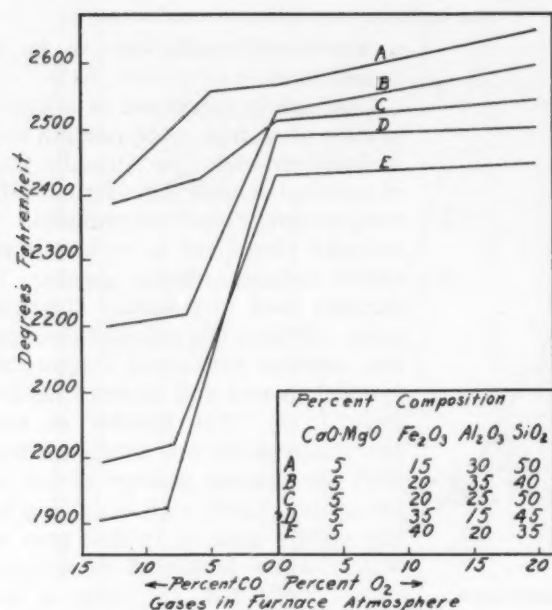


Fig. 9—Softening temperature of mixtures varying with composition of atmosphere

is probably combined with silica as clay or kaolin, and no reaction is necessary between these two oxides, except where an excess of silica exists in the form of fine quartz. When this is the case the reaction is simply a case of dilution.

Nichols and Selvig (12) of the U. S. Bureau of Mines give the following as typical limits of ash analysis:

SiO <sub>2</sub>	40-60	Fe <sub>2</sub> O <sub>3</sub>	5-25	MgO	0.5-4
Al <sub>2</sub> O <sub>3</sub>	20-35	CaO	1-15	Na <sub>2</sub> O, K <sub>2</sub> O	1-4

An observation of these limits reveals that the principal constituents of coal ash are: SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO and MgO. If the CaO and MgO are combined the number of principal dependent variables is four which may be plotted in the solid quaternary diagram. The writers have chosen to combine these two alkaline earth oxides in the ratio of 58.2 per cent CaO and 41.8 per cent MgO. This ratio was taken because the two oxides are found in nature combined in this ratio in the mineral dolomite, and it is probable that they exist in combination in coal ash either with each other or with the silica. The four dependent variables under consideration now are SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub> and CaO-MgO. The iron, as has been previously explained, will not remain present as Fe<sub>2</sub>O<sub>3</sub>, but because it is usually reported as such in silicate analysis, will be expressed as such in comprising one of the components of the quaternary diagram. There are a few coal ashes which exceed the limits given by the U. S. Bureau of Mines; and in order to follow tendencies exhibited within the limits, the scope of the investigation was extended to cover the area shown in the quaternary diagram Fig. 6. Only one of the equi-CaO.MgO have been investigated thus far, namely, the 5 per cent plane.

#### Experimental Work

Synthetic mixtures of the various compositions were prepared by the method of Andrews (13) for the wet blending of ceramic bodies, glazes and glasses. This method consists of mixing by weight the correct proportions of the three apices of the composition triangle, or of convenient intermediates called corners, to give all of the

desired points. The materials used for blending were either combined oxides, carbonates or finely divided single oxides. The CaO.MgO was weighed as dolomite in order to have a water-insoluble material for wet blending. This is necessary to avoid surface concentrations which would result from evaporation if soluble constituents were used. By adding the oxides in the combined form such as the addition of silica and alumina as kaolin, there is no possibility of their mechanical separation. In the coal ash they are usually found in the combined form as clay.

The corners after being weighed were mixed with water and ground in a pebble mill for ten hours. The weight-dry-factor of the resulting suspension was obtained by weighing a sample before and after drying and calculating the percentage of solids or oxides. The amount of the corner suspension necessary in making a certain intermediate is found by determining the amount of dry material of that corner composition which is necessary and multiplying this number by the weight-dry-factor. The suspension formed of the corners was blended in the liquid state and allowed to dry while being constantly agitated.

The materials used in making the corners of the field were added in the following forms:

Calcium Oxide CaO, massive dolomite, crushed and pulverized.  
Magnesium Oxide MgO, massive dolomite crushed and pulverized.  
Aluminum Oxide, Al<sub>2</sub>O<sub>3</sub>, kaolin or anhydrous aluminum oxides.  
Silicon Dioxide, SiO<sub>2</sub>, kaolin or pulverized silica (300 mesh).  
Iron Oxide, Fe<sub>2</sub>O<sub>3</sub>, ferric oxide (C. P. grade).

The cones were formed and tested in accordance with the standard procedure of the American Society of Testing Materials. There was, however, a slight change made, in that a magnifying quartz glass window was inserted in the sight tubes. This modification gave a more detailed view of the cones which materially aided observations and prevented rapid flow of gases through the crucible. A platinum-platinum rhodium thermocouple and a Leeds and Northrup potentiometer were used for temperature measurements. The thermocouple was calibrated during each test by comparison with the melting points of gold and nickel. Duplicate tests were made in the gas furnace on all corners and intermediates in five per cent steps. Very good checks were obtained in most cases, never reaching the variance allowable in the A.S.T.M. method for duplicate samples of coal ash run in the same furnace by the same operator, i.e., 54 F. In general, the compositions having a short temperature interval between the initial deformation temperature and the softening temperature gave better checks than those having a long temperature interval.

The initial deformation temperature is the temperature at which a standard size cone shows the first evidence of melting. This is usually exhibited by a sharp bending or rounding of the point of the cone. A slight change of position from vertical to a slightly curved shape does not constitute deformation, nor does a slight bloating effect caused by decomposition evolving gases. The softening temperature is that temperature at which the cone reaches a spherical shape above the base.

Using the data thus obtained a triangular diagram of the 5 per cent CaO.MgO plane was constructed for the area covered. With the per cent silicon dioxide, aluminum oxide and iron oxide as the dependent variables contour lines of the initial deformation temperatures were



A careful examination of these two figures will show why previous attempts at relating alumina-silica ratio or acid-base ratio to the fusion or ash have failed. It can also be seen that within certain limits such relationships can be found. The general characteristics of the contour lines indicate that the figures bear some relation to a liquid-solid phase diagram of the components involved but the relationship is not exact.

The most obvious area in the figures is the low melting portions directly above 25 per cent  $\text{Fe}_2\text{O}_3$  and less than 20 per cent  $\text{Al}_2\text{O}_3$ . While few coal ashes fall in the center of this area, several do approach it and are influenced by it. Probably the most interesting speculation in regard to the use of this area is for producing a low fusing ash for boilers in which the ash is removed in the form of molten slag. It appears probable that the addition of an iron-silica ore would be most helpful in this respect by raising the iron content of low-iron coal ashes and lowering the average alumina content of the mixture. On the other hand, addition of aluminum oxide decreases the average iron and silica percentage and may give a higher fusing mixture. Other factors however would also have to be considered in a practical application of this fact to furnace conditions.

The ability to produce a lower or higher fusion ash by the mixture of two or more coals depends on crossing contour lines when a straight line is drawn between the composition of each ash. If the line so drawn runs parallel to the contour lines no advantage can be gained since no higher or lower region will be met by any mixture. The closeness of the contour lines on the low alumina side of the diagram indicates a rapid rise in the fusion temperature of the ash with a small decrease in alumina content.

The data for softening temperatures used in the construction of Fig. 8 agrees in general with a limited chart recently made by Estep (14), et al. from coal ash analyses showing about 5 per cent calcium oxide. The latter chart does not cover as wide an area of composition as Fig. 8 and hence does not show the influence of adjoining areas. Other charts from their data indicate that the content of lime from 2.5 per cent to 8.5 per cent changes the fusion temperature less than 100 F in most cases.

Figs. 7 and 8 are sufficient to show that a relationship does exist between composition and fusion temperature and what that relationship is within the limits of composition covered by this work.

The state of oxidation of the iron in the coal-ash mixture is another factor influencing the fusion temperature as determined in the laboratory and also in boiler furnace operation. At one time or another all states of oxidation may be found in furnaces. The writers have seen the iron in clinkers from stoker-fired boilers in the form of  $\text{Fe}_2\text{O}_3$  probably resulting from the replacement of the sulphur of pyrite with oxygen. On the other hand, large pieces of metallic iron have been found in slag taken from the bottom of slagging-type pulverized fuel boilers. Black glassy slags of ferrous aluminum silicate are the common by-product of the latter type furnace. The

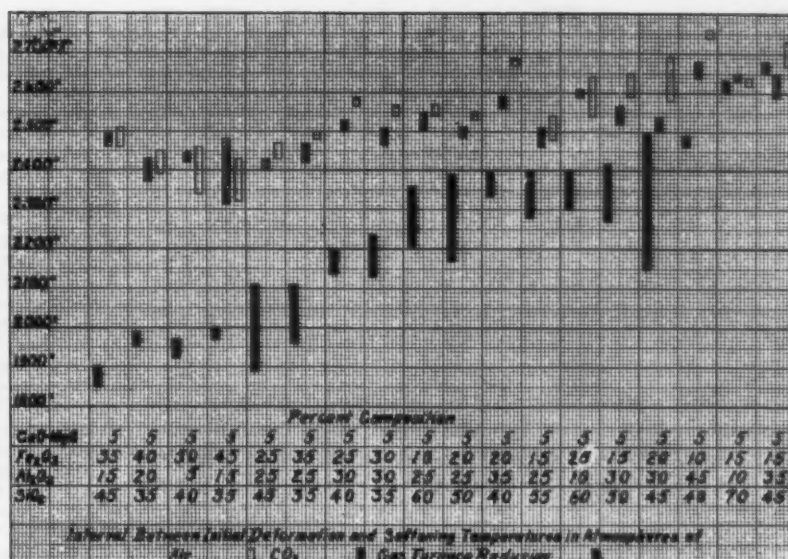


Fig. 10—Showing effect of furnace atmospheres on both initial deformation temperatures and softening temperature as related to ash composition

condition of the iron is greatly influenced by the nature of the surrounding gases.

To determine the effect of different atmospheres on ashes of various compositions duplicate samples were tested in four atmospheres: 1, maximum obtainable reducing conditions in an A.S.T.M. gas-fired fusion furnace; 2, minimum obtainable reducing conditions in the same furnace; 3, an atmosphere of carbon dioxide in a silicon carbide resistor furnace; and 4, an atmosphere of air in the latter furnace. Figs. 9 and 10 were constructed from data so obtained.

In Fig. 9 softening temperatures of typical samples are plotted against the per cent CO and O<sub>2</sub> in the surrounding atmosphere and the composition of the mixtures are noted. These curves show that the critical concentration of CO lies between zero and eight per cent. The oxidation potential as shown by the per cent oxygen does not have a marked effect on samples already oxidized but might be more critical on ashes containing reduced or reducing materials. It is most important to note that low fusing ashes become quite refractory under oxidizing conditions but higher fusing ashes are not greatly influenced by changes in the surrounding atmosphere. This is a probable explanation of certain difficulties experienced with low fusing coals in one furnace when another furnace under different operating conditions has no trouble at all.

Fig. 10 is a more comprehensive diagram on the effect of furnace atmospheres on both the initial deformation temperatures and the softening temperatures as related to ash composition. The lower end of each block represents the initial deformation temperature and the upper end the softening temperature, the entire block showing the fusion interval. In general, it is the high iron coals which are influenced the most by changes in the furnace atmosphere. In this figure samples which may melt as low as 1900 F under reducing conditions are still solid at temperatures of 2300 and 2400 F under neutral or oxidizing conditions. This fact has been utilized in slag-tap furnaces by drawing furnace gases near the tapping door not only to maintain the temperature but also to keep the slag in a reduced condition during the tapping operation.

The short temperature interval indicates that when the fusion temperature is reached the melting of the ash will occur suddenly whereas with the longer interval as in most of the reducing conditions there is a slower fusion with generally the formation of a more or less viscous melt.

This latter quality of the ash is important in evaluating the free running temperature of the ash and, to a certain degree, its clinkering characteristics. It has been the writers' experience that coal ashes which have long fusing intervals form clinkers of a vesicular nature which are not very hard to break up and remove from the fire grate, while ashes having a short interval usually form glassy slags. At very high temperatures all slags become dense. The glassy appearance or the dull matt appearance of the ash is also a function of composition but sufficient data have not been collected to state what this relation is. It is sufficient to say that some slags will not get glassy regardless of the temperature to which they may be submitted while others turn glassy immediately after reaching the softening point.

In practice, however, the softening temperature as determined in the laboratory is not always a direct function of the clinker characteristics of the coal. This means that the composition of a representative sample will not give an invariable indication of what characteristics the coal may exhibit in the boiler. The writers in an earlier paper (15) pointed out some discrepancies in the A.S.-T.M. method and offered a substitute test, which reveals the nature of the ash better and which offered an explanation for many exceptions to the rule: high fusion good clinker characteristics; low fusion poor clinker characteristics.

In addition to using these data for the study of ashes, they may also be applied to the study of reactions between the boiler refractory and ash. A knowledge of the composition of refractories and of the ash and their reaction characteristics may be of considerable help in the selection of the proper type of refractory. As an example, it would not be the wisest thing to do to put a high alumina refractory in a fire box where a coal is burned which has a moderate fusion temperature but is of such composition that the addition of a small amount of alumina would materially lower its fusion temperature.

### Conclusions

As a result of laboratory experiments the following conclusions are made:

1. That the fusion temperature is a function of the composition of coal ash.
2. That the blending of coal ashes may result in a predetermined mixture of higher or lower fusing ash.
3. That the viscosity, crystalline and glassy phases of melted ashes are related in an undetermined manner to the composition.
4. That the magnitude of the effect of reducing gases on an ash is a function of the composition.
5. That erosion of refractories is dependent on ash composition.
6. That much knowledge may be gained concerning the general characteristics of ash by a study of their relation to the chemical composition of the ash.

### Bibliography

- (1) A.S.T.M. Standards, American Society for Testing Materials, p. 994 (1924).
- (2) Tammann, G., and R. F. Mehl, "States of Aggregation," p. 283, D. Van Nostrand Co. (1925).
- (3) Maxwell, J. C., *Science Papers*, v. 2, p. 620, Cambridge (1890).
- (4) Taylor, H. W., "Elementary Physical Chemistry," p. 127, D. Van Nostrand Co. (1928).
- (5) Wilson, H., "Ceramics," p. 203, McGraw-Hill Book Company (1927).
- (6) Rankin, G. A., and F. E. Wright, *Am. Jour. Science*, v. 39, p. 11 (1915).
- (7) Johnson, J. E., "Principles, Operation and Products of the Blast Furnace," McGraw-Hill Book Company (1918).
- (8) Bancroft, W. D., "The Phase Rule," p. 149.
- (9) Hostetter, J. D., and H. S. Roberts, "Note on Dissociation of Ferric Oxide," *Jour. Am. Ceram. Soc.*, v. 4, p. 927-938 (1921).
- (10) "International Critical Tables."
- (11) Eastman, "Equilibrium Constants and Temperature in the System, Iron, Carbon and Oxygen." U. S. Bur. Standards Sci. Paper 350 (1919): *Jour. Am. Ch. Soc.* 44 pp. 975-998. (1922).
- (12) Nichols, P. and W. A. Selvig, *Fuel* (London) XII, p. 156.
- (13) Andrews, A. I., "Ceramic Tests and Calculations." John Wiley & Sons, Inc., p. 91 (1928).
- (14) Estep, T. G. et al. "Effect of Mixing Coals on the Ash Fusion Temperature," *Carnegie Inst. Bulletin* 62 p. 23.
- (15) Moody, A. H. and D. D. Langan, "Fusion Characteristics of Fractionated Coal Ash," *Combustion*, October 1933.

### 1935 Power Shows

Plans are under way for two independent power shows this year, in addition to the usual exhibit held in conjunction with the Annual N.A.P.E. Convention at the William Penn Hotel in Pittsburgh, August 26 to 30.

The first of these, scheduled for June 24 to 28, will be unique in that it will be held afloat. This is the Great Lakes Power Show and Mechanical Exposition to be staged aboard the steamship *Sealandbee* which will spend a day each in Buffalo, Cleveland and Detroit, thus affording the advantages of a local exhibition for each city and thus making it possible for local engineers, who might find it inconvenient to take time from their work for traveling, to attend.

The second is the Midwest Engineering and Power Exposition to be held at the Coliseum in Chicago the week of September 16. This exposition has not been held for more than two years and will cover the field of power generation, application and allied services.

### FERA Engineers Making Power Survey

Following Mayor La Guardia's threat to build a municipal power plant, or plants, to serve public buildings and street lighting in New York City, the Department of Water Supply, Gas and Electricity has recruited seventy engineers from the FERA who have been put to work surveying the requirements of certain city areas. The proposed plan is to construct several plants each serving a group of buildings and services and to tie in if possible with the plant which the federal government contemplates erecting to meet the needs of a group of federal buildings. The extent to which these city plans will be carried out in serving municipal requirements will probably depend upon the outcome of pending negotiations with the local utility.



# Metallurgical Data on Fusion Welded Joints

On January 14 a "Symposium on Recent Developments in Welded Pressure Vessel Construction" was held at a joint meeting of the American Welding Society and the Metropolitan Section of the A.S.M.E. in New York. Three papers were presented one of which, prepared by A. J. Moses,<sup>1</sup> dealt with the metallurgical aspects of welding. Some excerpts from this paper are here briefly reported. The American Welding Society anticipates publication of all three papers in greater detail in an early issue of its Journal.

**W**ELDING is a metallurgical operation. By treating and checking it as such the quality of fusion-welded joints is being controlled to the end that they meet or exceed the base metal requirements in connection with carbon steel and many of the other alloys and metals used in pressure vessels. That this control exists is proved by the mass of evidence

the action cannot progress except in the presence of oxygen or some oxidizing agent. From a materials standpoint the hydrogen ion value cannot be controlled, and the presence of oxygen only partially so. Differences in potential which lead to galvanic action can be controlled within limits considered satisfactory on the basis of experimental and service results. Anomalies arise here in that certain impurities are beneficial although they also cause a difference in potential. This indicates that initial, minor potential differences are rather unimportant and are outweighed by the promotion of self-protecting films or structures. Also, galvanic action can retard as well as assist local corrosion.

## *Internal Influences Causing Corrosion*

The corrosion of metals may be due to external or internal influences or both. This discussion will be confined to internal influences. The following factors affect the physical and corrosive resistant properties of base materials and welded joints: Chemical composition, cleanliness, stress condition and structural composition. It is best that the chemical composition of containers or pressure vessels be approximately uniform throughout, but this must be tempered so as not to forbid the use of plates from different heats or hammer or fusion welded joints of slightly lower carbon content. However, practically the same grade of material should be used throughout to eliminate the possibility of major potential differences.

Fig. 1 illustrates the desirability of maintaining chemical uniformity in the joining of plates. Specimen A shows the results from an immersion nitric acid corrosion test on 18 per cent chrome, 8 per cent nickel, stainless weld metal deposited in 16-18 per cent chrome iron plate. It will be seen that the austenitic weld metal has not been affected, whereas the adjacent plate stock has been badly corroded. Specimen B shows the results obtained from the same test on a properly annealed 16-18 chrome weld joint deposited in plate material of the same analysis. Specimen C shows the results on a properly heat treated 18 per cent chrome, 8 per cent nickel weld joint deposited in plate of that analysis.

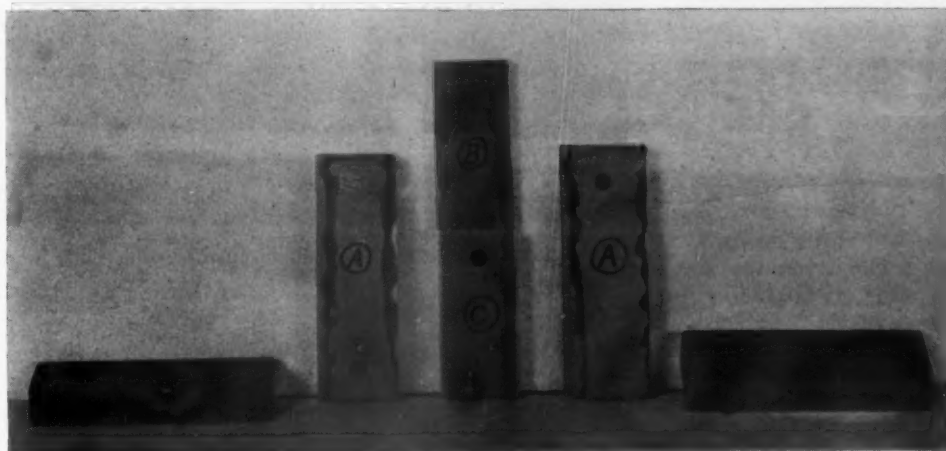


Fig. 1—Illustrating desirability of maintaining chemical uniformity

gained from destructive tests of fusion-welded pressure vessels, as well as from the statistical data of physically tested weld samples. The results here reported are based not only on investigations by the author but also on information furnished by the Class One Welding Association.

The prevailing theory of corrosion is that it is an electro-chemical action, that this action is primarily due to the hydrogen ion and galvanic action and that

<sup>1</sup> Mr. Moses is Assistant General Manager of the Hedges-Walsh-Weidner Company, Chattanooga, Tenn., and the paper was read by A. C. Weigel of Combustion Engineering Company, Inc.





Fig. 2—Unetched hammer-weld joint showing slag inclusions

The tables give the chemical range for the various component parts that may enter into the fabrication of completed pressure vessels and tanks of ordinary carbon steel. They also show that controlled fusion welding

CHEMICAL VARIATIONS THAT MAY AND DO OCCUR IN THE COMMON MATERIALS THAT ARE USED IN THE CONSTRUCTION OF PRESSURE VESSELS

	Carbon Per cent	Manganese Per cent	Silicon Per cent	Phosphorus Per cent	Sulphur Per cent
Plate	0.12 to 0.35	0.30 to 0.60	Up to 0.30	Up to 0.04	Up to 0.04
Rivets	0.05 to 0.15	0.30 to 0.50	.....	Up to 0.04	Up to 0.045
Forgings	0.20 to 0.50	0.50 to 0.80	.....	Up to 0.05	Up to 0.05
Steel					
Tubes	0.08 to 0.18	0.30 to 0.60	.....	Up to 0.04	Up to 0.045
Iron					
Tubes	Up to 0.03	Up to 0.03	.....	Up to 0.02	Up to 0.045
Steel					
Castings	0.15 to 0.45	0.50 to 0.80	Ave. 0.20	Up to 0.06	Up to 0.06
Cast	0.50 (combined)				
Iron	2.85 (graphitic)				
Total	3.35	0.65 to 0.90	1.2 to 2.2	0.1 to 0.4	0.07 to 0.12

ACTUAL CHEMICAL VARIATIONS FOUND IN A LARGE NUMBER OF ANALYSES OF BARE WIRE WELD METAL, COATED ROD WELD METAL AND PLATE STOCK OF 55M TO 65M TENSILE STEEL

	Bare Wire Weld Per cent	Coated Wire Weld Per cent	Plate Stock Per cent
Carbon	0.02 to 0.08	0.07 to 0.16	0.12 to 0.30
Manganese	0.10 to 0.20	0.29 to 0.61	0.33 to 0.62
Silicon	Nil. to 0.015	0.05 to 0.31*	0.01 to 0.12
			0.14 to 0.28*
Phosphorus	Less than 0.04	0.01 to 0.035	0.01 to 0.04
Sulphur	Less than 0.04	0.01 to 0.038	0.011 to 0.041
Nitrogen	0.10 to 0.15	0.01 to 0.035	0.002 to 0.007

\* (Silicon Killed Steel)

compares closely with the chemical composition of plate material; much closer than do forgings, castings and bare wire weld metal. Bare wire weld metal is low in those elements such as carbon, manganese and silicon

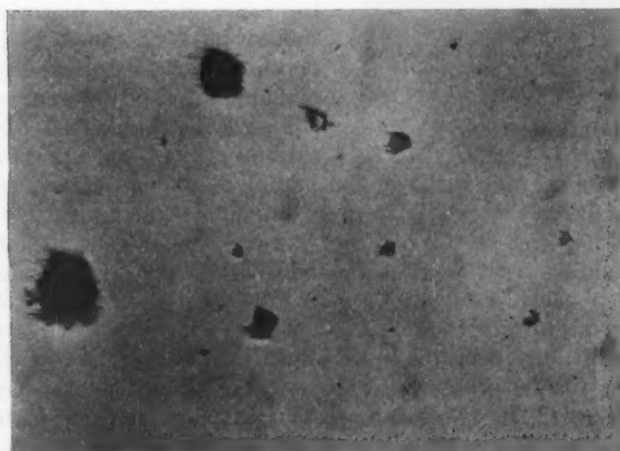


Fig. 3—Bare-wire weld metal showing typical large oxide inclusions (unetched)

which produce soundness and good properties and is high in such inclusions as FeO and N<sub>2</sub> which promotes unsoundness and brittleness. On the other hand, coated wire weld metal shows a proper amount of the beneficial



Fig. 4—Macro section of fusion weld showing badly corroded layer of weld metal deeply etched

elements and the only oxide present in quantity is silica which is beneficial rather than detrimental.

By cleanliness is meant absence of injurious impurities such as oxides, nitrides, slag inclusions, etc. Some metallic impurities may be harmless, in themselves, yet if badly segregated may promote galvanic action. It is the non-metallic inclusions that are doubly injurious in that they cause potential differences and may furnish the oxygen necessary for the progression of electrolysis. The large amount of these always present in electric arc welding done with an unshielded arc is undoubtedly a large contribution to the poor corrosion resistant properties of such metal. Entrapped slag in hammer

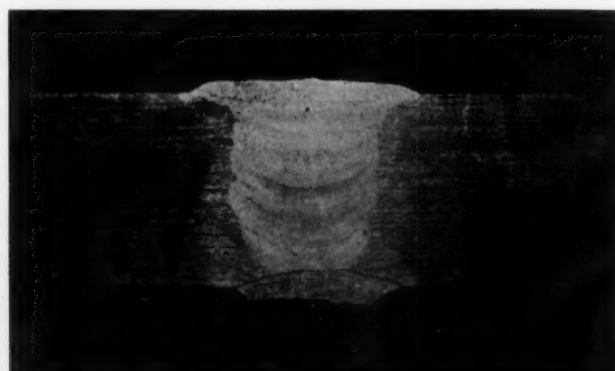


Fig. 5—Macro section of controlled fusion weld (deep acid etched)

welded joints, once exposed, makes them subject to rapid corrosion. Fig. 2 is a photo-micrograph of an unetched hammer weld joint showing entrapped slag, and Fig. 3 (unetched) shows typical large oxide inclusions in bare wire weld metal.

In order to eliminate the defects inherent to bare wire welding, heavily coated electrodes are being used. But in order to obtain good clean weld metal of desirable physical and corrosion resistant properties, strict control must be maintained over the weld rod composition, the coating composition, the application and the welding technique. As an illustration of a lack of control Fig. 4 shows a badly corroded layer of weld metal after deep etching with 1:1 HCl.

Fig. 5 is a transverse cross-section through a typical field of controlled fusion weld metal made with heavily coated electrodes (deep etched) showing sound characteristics. The denseness of the deposited metal is even superior to commercial steel.

Fig. 6 represents photographs of corrosion test samples illustrating the relative action of 20 per cent HCl at 130 F on various types of fusion welding. Specimen *a* shows rapid attack on bare wire welding; specimens *b* and *d* show only slight attack on controlled fusion welds, while *c* and *e* show only fair results obtained with improperly shielded arc welding. The actual specimens show that the plate stock has been corroded to a greater extent than the weld metal.

The combined action of stress and corrosion has led to many disastrous failures. This type of corrosion is usually intergranular. Losses in elongation and in endurance limits in stress reversing fatigue tests are accepted as a measure of this type of corrosion attack.

#### Control and Elimination of Embrittlement in Boiler Plate

The intergranular corrosion of ordinary boiler steel under certain conditions, commonly known as caustic embrittlement, has long been a problem of concern. From information obtained from about 400 cracked, riveted, boiler drums and numerous laboratory experiments, Parr and Straub reached the following conclusions: "Embrittlement in boiler plate is caused by the combined action of stress and chemical attack. The stresses are inherent in the construction and operation of the boiler while the chemical attack is caused by the presence of sodium hydroxide in the water." Also, "No steel

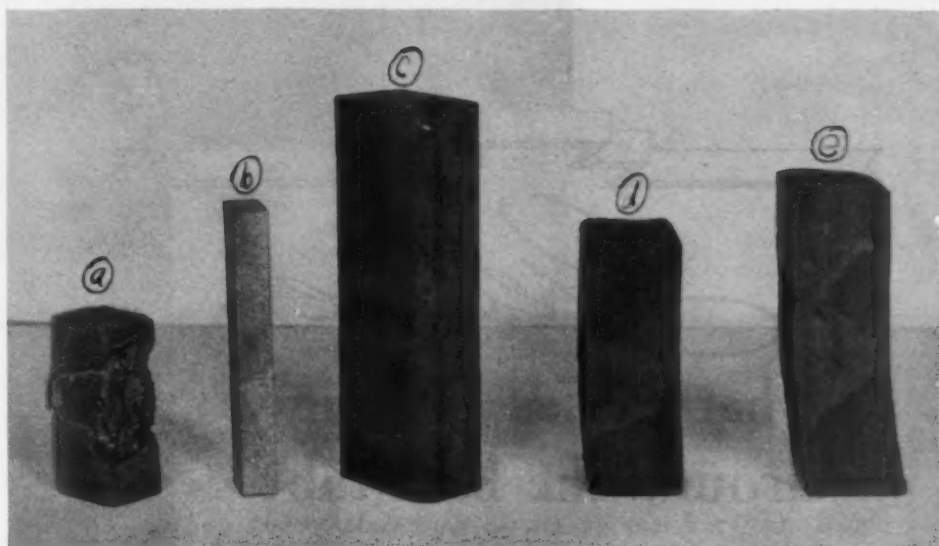


Fig. 6—Samples of various types of boiler plate welds showing relative corrosive action of 20 per cent HCl at 130 F for 3 hr

Fusion-welded joints must be thermally stress relieved in order to develop the most desirable physical and corrosion resistant properties. Corrosion tests of unstress-relieved welds have given erratic results. Stress relieving only slightly improves the physical properties of bare wire weld metal and does not improve the corrosion resistant properties. In fact, there are indications that with bare wire weld metal stress relieving actually reduces the corrosion resistant properties. This can be explained by the precipitation of nitride needles.

#### Finer Grained Material Less Susceptible to Intergranular Corrosion

The effect of structural composition on the corrosion resistant properties of metals is not so evident as that of chemical composition, cleanliness and stress con-



Fig. 7—Panorama micrographs through shielded metallic arc welded joint

suitable for boiler plate has been found which is resistant to the embrittling action of caustic soda." These authorities state that one would expect to be able to stop the cracking by one of the following methods:

- Prevent the caustic boiler water from concentrating
- Eliminate the highly stressed areas
- Neutralize or inhibit the action of the concentrated caustic

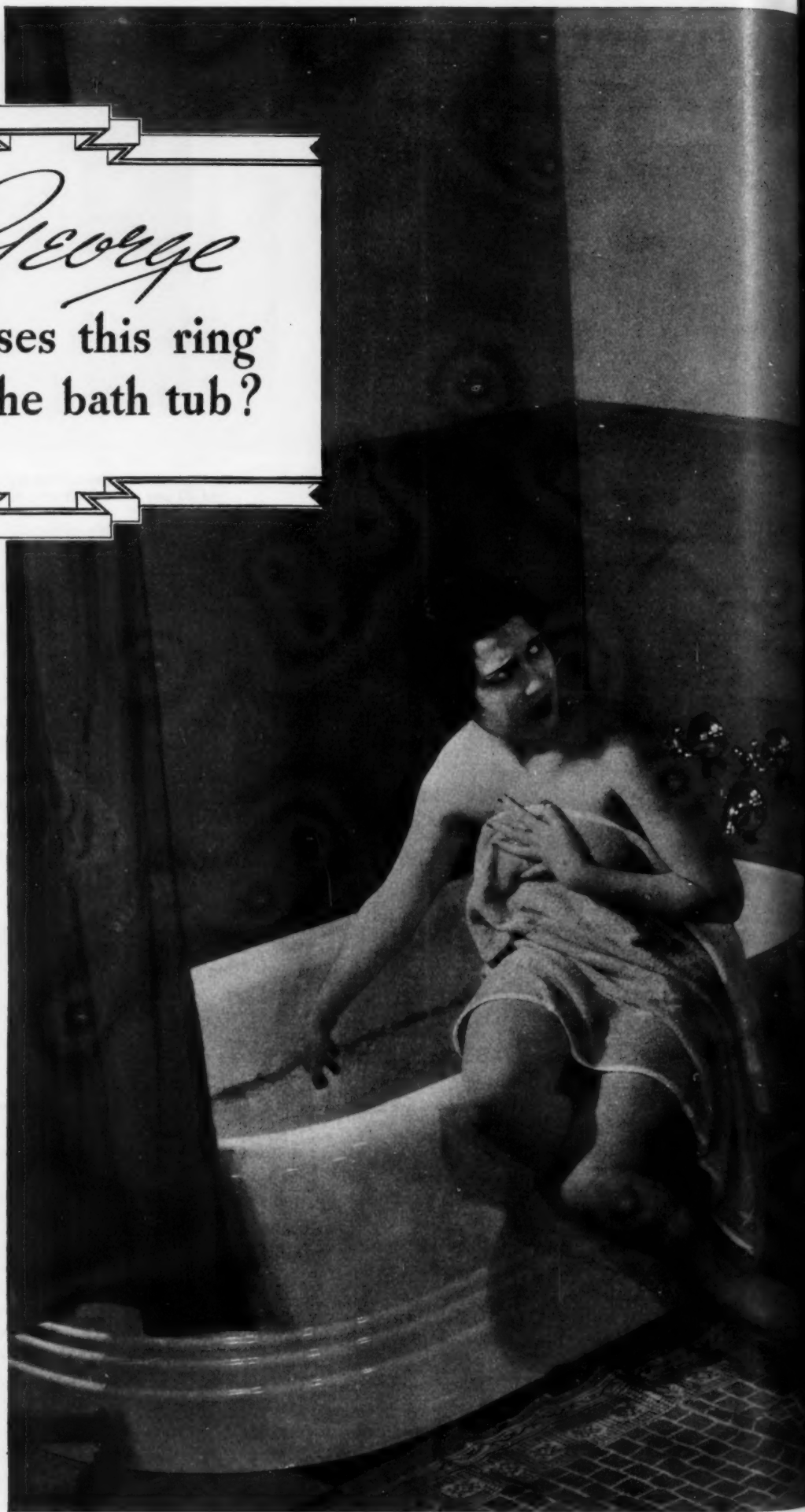
Experience with new boilers indicates that caustic embrittlement can be controlled by either of these methods, but method *b* is fundamentally correct in that it is not subject to possible errors in maintaining continuous control as necessitated by methods *a* and *b*. Stress relieved fusion-welded boiler drums have practically eliminated the trouble due to caustic embrittlement.

ditions, but under stress corrosion coarse structure is not expected to be as resistant to intergranular action as very fine grain shielded metallic arc welds such as are obtained in multiple thin layer deposition. If of the same degree of cleanliness, the finer grained material offers more grain boundaries which leads to a greater dilution of impurities along these boundaries. This, in turn, leads to a less rapid intergranular corrosion.

Fig. 7 shows in panorama micrographs at 100 magnifications through a shielded metallic arc welded joint; *a* to *f*, in the order shown reveal the gradual merging of unaffected plate and weld metal with no suggestion of a carbide segregation. Such weld metal and affected stock has excellent physical properties with no directional tendencies, and in addition is equal to and generally superior to the base metal in corrosion resistant properties.



*George*  
what causes this ring  
around the bath tub?







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# Overall Station Heat Consumption as Affected by Condensing Water Temperature

By recirculating the condensing water during the cold months and thereby raising the average inlet water temperature from 32 F to around 40 F or greater, depending upon the load, a net annual saving, due to increased turbine efficiency, of \$4230 was effected. In addition, it has eliminated the service hazard due to ice.

By C. F. MOULTON  
Assistant Operating Engineer  
Nebraska Power Company

FOR a number of years it was noted that our monthly overall steam station economy was lower when the condensing water was at 32 F than when it averaged 40 or 50 F; this despite higher vacua, reduced circulation—to obtain a minimum of condensate refrigeration—and a decrease in auxiliary power for circulation purposes.

From January 1926 until May 1930, practically the entire load was carried on two units of 20,000 kw each, and operating with steam conditions of 300 lb gage and 700 F temperature. During that period the combined turbine efficiency on the basis of total generation was approximately as shown by the A curve in Fig. 1. On the basis of this curve, it was estimated that if the circulating water temperature were held between 40 and 50 F instead of 32 F, three-tenths of one per cent saving could be effected.

Using:

Average monthly output.....	27,000,000 kwh
Average annual number of days of 32 F circulating water.....	110 days
Saving in Btu per kwh for each 0.1 per cent increase in turbine efficiency.....	65 Btu

Then:

$$\frac{27,000,000 \times 110 \times 65 \times 3}{30} = 19,305 \text{ million Btu per season total savings}$$

At an approximate cost of 15 cents per million Btu, the possible saving seemed to be close to \$2900 per annum.

The last of April 1930, a new unit of 25,000 kw capacity was put in service. After that date the combined efficiency versus the circulating water temperature curve for the three machines, as plotted from monthly data, became as shown by curve B in Fig. 1. This combination

was much more efficient in general, but apparently the loss due to cold circulating water was more than it had been prior to the installation of the new unit. This was attributed to the fact that under even the best load conditions the condensate depression on the new unit was slightly more than the average depression on the other two machines. The possible saving with this new arrangement was calculated to be about \$3870, instead of \$2900 as with the previous conditions. Since general performance data were desirable, and since a specific problem in connection with circulating water temperatures seemed apparent, a series of tests on this new unit was started early in 1932. Thirty-three tests were run during the year, covering the annual range of circulating water temperatures at ten degree intervals and covering the load at 15,000, 20,000 and 25,000 kw. These tests resulted in confirmation of the previous observations.

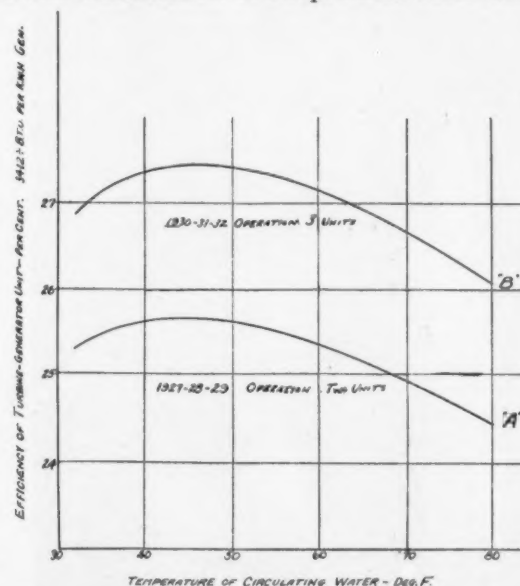


Fig. 1—Turbine-generator unit efficiency vs. circulating water temperature

Fig. 2 is designed to show graphically the relationship between economy and circulating water temperatures at different loads. The A curves in this figure are adaptations of the manufacturer's vacuum correction curves on

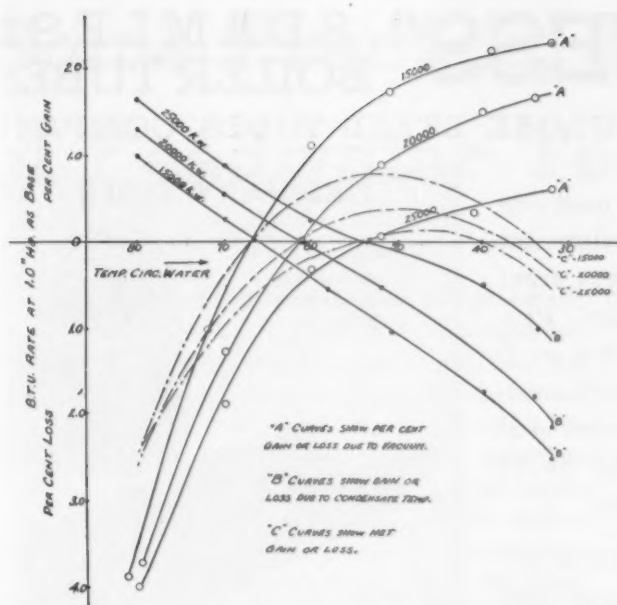


Fig. 2—Change in heat rate due to change in circulating water temperature, 25,000-kw unit

this machine and show per cent loss or gain in heat consumption above and below one inch absolute exhaust pressure as a base. These differ from the manufacturer's curve only in that these have as abscissae the condensing water temperatures corresponding to the absolute pressures obtaining during the tests, instead of the absolute pressures at the condenser flange as used for the manufacturer's curves.

The B curves are plotted from test data and show the per cent loss or gain due to condensate temperature with 80 F (1 in. absolute pressure) as a base. The following equation is used in determining points for these curves.

$$\frac{\text{Pounds condensate} \times (80 - \text{temperature of condensate}) \times 100}{\text{Total heat chargeable to unit at base condition of 1" Hg abs pressure}} =$$

Per cent loss or gain, depending on sign of the numerator

The C curves are derived from the other two sets of curves and show net gain or loss due to circulating water temperature. It is readily seen from these curves that the most desirable range of circulating water temperature is as follows:

Load	Circulating Water
25,000 kw	45 to 50 F
20,000 kw	48 to 53 F
15,000 kw	53 to 58 F

The curves shown in Fig. 3 are derived from actual heat consumptions at one inch absolute exhaust pressure as a base with percentage loss or gain according to the C curves of Fig. 2 applied to this base to give the various points on the curves. Actual test results are very close to these curves, the variations, where they exist, being easily explainable due to variable extraction steam demands of the system.

#### Improvement Due to Recirculation

The results of these studies and the several years of operating experience were instrumental in obtaining an appropriation for building recirculating equipment.

Since continuity of service is of paramount importance, and since ice at the intake had caused considerable trouble, even to the point of partial plant shutdowns, there was a double reason for desiring such equipment. The recirculation equipment consists of a floating structure having slots through which planks are lowered to shut off part of the flow of river water to the intake and to direct the flow of part of the discharge water back to the intake.

This recirculation was put into operation in the fall of 1932 with 40 F established as the desirable temperature at which to hold the circulating water. During the year 1933, the turbine efficiencies followed the curve B of Fig. 1 very closely with maximum efficiencies of 27.4 per cent with 39 F water in March and the same with 51 F water in April. The efficiencies during 1934 followed the same curve but were consistently lower by 0.7 per cent due to increased load. During the two years of operation with partial recirculation of condensing water through the cold months, there has been no service hazard whatever due to ice, and there has been no drop in efficiency during those months. The approximate saving is calculated to be \$4230.

Average annual cost chargeable to extra labor on account of ice before 1933.....	\$760.00	
Annual loss due to drop in efficiency (basis: present conditions).....	3870.00	\$4630.00
Annual maintenance expense on recirculating equipment.....	250.00	
Chargeable to depreciation of recirculating equipment—25 per cent on \$600.00.....	150.00	400.00
<b>NET GAIN.....</b>		<b>\$4230.00</b>

It is felt that this represents a worth-while saving in addition to removing a service hazard from ice accumulations in the condenser intake as had previously been experienced.

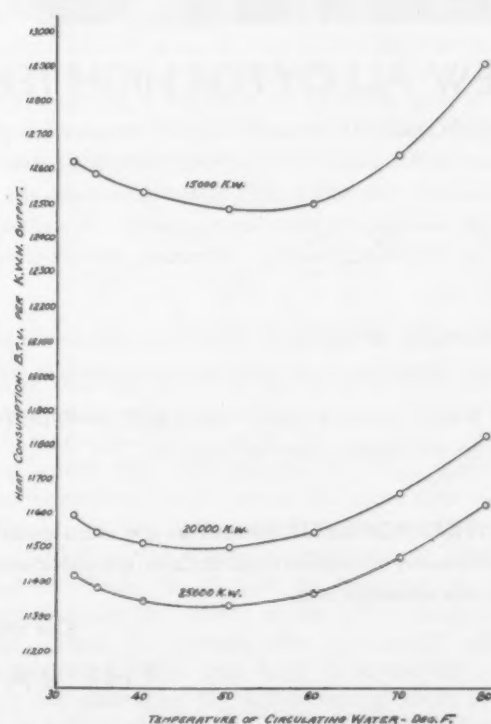


Fig. 3—Heat consumption vs. circulating water temperature, 25,000-kw unit



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# Some Practical Interpretations of Feedwater Tests

The author points out how simple, daily routine tests by the operating engineer, for controlling the water conditioning, can be utilized to reveal much additional information, such as the condition of the boiler, leaky blowoff connections, whether the blowdown is excessive, waste in carry-over, ratings being carried and the detection of pending trouble. In these the salt and alkalinity readings are indicative. Examples illustrating the several cases are included.

WHILE the correct interpretation of simple daily tests of the blowdown water at a plant provides by far the most satisfactory guide for the engineer in controlling the conditioning of boilers against scale depositions and corrosion, these same tests alone, and when measured against simple tests of the raw water, feedwater and condensed steam, provide definite means for determining:

- The boilers that are leaky, inefficient and wasteful;
- The best steaming boilers;
- The uniformity with which the soda treatments are being distributed;
- The per cent of make-up water;
- The per cent waste through carryovers;
- The boiler rating;
- The boilers that are blown down excessively;
- The pounds of water evaporated per pound of fuel.

The results obtained through such tests of representative samplings are equal to the best measuring and metering devices employed for the same purpose. Where this is combined with the use of testing solutions that are prepared by reliable water chemists, the results are most dependable.

Use of representative samples and standardized solutions is especially necessary where the salt or alkalinity in the water tested is low, but the accuracy of all tests can be greatly increased again by concentrating 10, 25, 50 or 100 volumes into one, the number depending upon the extent of the test reading and the required exactness of the corrected reading. The quotient obtained by this division gives the most accurate measure of the amount of the specific water constituent for which the evaporation is made.

For example, assume that the salt content in a sample of feedwater is found to be 0.7 gr per gallon. This is a rather low reading for these other uses, and for greater accuracy it is therefore necessary to concentrate a sample of the feedwater. Suppose this concentration is 25 times and the titration of the same gives 12 gr of

By CYRUS WM. RICE

Water Chemist and Engineer,  
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salt. Then, 12 divided by 25 gives 0.48, which is the more accurate measure of the salt content of the sample tested.

The engineer who is in a position to make the regular daily tests and to carry out the determinations, possesses an inexpensive and invaluable means for the *definite detection of trouble and waste under steaming conditions.*

With all the standardized solutions in hand and broader applications of these daily tests by the engineer, there is every reason to avoid many of the losses which take place in boiler operations and at the same time supply more interesting conclusions to what is usually the routine operation of testing boiler waters for treatment control purposes only. Because of this and the tendency to place the conditioning of the boiler feedwaters on a more scientific basis, I feel that a detailed practical presentation of these other uses should prove valuable to those engineers who are not provided with water and steam metering devices.

The early part of this discussion will be limited to the tests which are now a matter of daily routine at many plants. I refer here to the phenolphthalein, methyl orange and chloride (salt) tests of the boiler waters. With this object in view attention will first be directed to the tests of the boiler blowdown water only. For the wider application of these it is also suggested that the same tests be made on each steaming boiler. A typical example of a set of these daily tests for a plant follows:

EXAMPLE I

Boiler No.	Alkalinity		Salt Conc. Blowdown	Steaming Hours
	Pht.	M.O.		
1	10.0	13.0	20.0	2545
2	30.0	35.0	37.2	2790
3	19.0	23.0	39.6	2824
4	3.1	4.5	8.0	2260
5	15.0	18.5	49.2*	450

Assume that the plant in which these tests are made is not equipped with flow meters or steam calorimeters; also, that all the boilers, with the exception of No. 5, steamed about the same length of time, operated at near the same rating and were of the same type. Under such conditions the salt concentrations in the various units included in the example should be in fairly close agreement. Even No. 5 unit in this case should not vary much from the others in its salt or soda concentrations. This is because the maximum allowable concentration a boiler can hold is invariably reached in much less time than the 450 steaming hours indicated for No. 5 boiler, unless other conditions such as priming, leaky tubes, boiler types, etc., prevent.



A review of all the tests reported under Example I shows a marked difference in both the salt and alkalinity readings, the salt alone varying from 5.6 gr in No. 4 boiler to 49.2 gr in No. 5 boiler. While this difference is radical it is not uncommon in boiler operation and pictures accumulative variables which are not exposed through either steam or water meters. These inequalities can be caused by,

Leak blow-off and column valves;  
 "Hit or miss" methods of blowing down;  
 Irregular firing;  
 Inefficient firing;  
 Broken baffles;  
 Leaky tubes and header caps;  
 Priming.

Regardless of the cause, the wide constant variations in salt concentrations are preventable and the reasons should be located and corrected. Where such irregularities exist the first move is to feel the blow-off pipe on each boiler. In such an inspection the leaky valves are always hot and with few exceptions point to the boilers which carry the lower salt concentrations, especially where this leakage has been allowed to continue for some time.

The cold blowoff pipes also are invariably connected into the tight blowoff valves and the boilers to which they apply usually maintain the higher salt concentrations. What is true of the blowoff valves with respect to its influence on the boiler concentrates also applies to the column valve, boiler tubes and header caps. Each of the connections mentioned and all under-water joints affected by leakage have their influence in causing different salt concentrations, the same depending upon the extent of the under-water leakage and the boiler pressures carried.

In practice, it is surprising the influence a small opening has in keeping the salt concentrations down. In tests actually carried out on steaming units a measured opening of  $\frac{1}{16}$  in. diameter was sufficient, in boilers operating at 300 lb pressure and 200 per cent rating, to keep the salt low enough without blowing down.

The same irregularities as those caused by leaks also hold with the "hit or miss" methods of blowing down boilers in which there is no definite control exercised over the volume and number of blowdowns in relation to the requirements or operating conditions. Should the inspection of a plant show all boilers to be tight against leakage and the blowdowns to be under systematic regulation, the cause for these irregularities in salt concentrations may be due to faulty drafts, poor firing or broken baffles. Just what bearing any one or more of the mentioned influences has in causing the different concentrations should be determined whenever the opportunity permits.

Again, for an unknown reason some boilers are better steamers than others. This is not an uncommon occurrence in a boiler room where the setting, firing, etc., of all the steaming units is known to be good. While this knowledge is usually gained by experience in firing, the comparison of the individual salt tests each day clearly indicates whether or not this is true.

The worst steaming boiler in a house is also generally known to an operator in the same way and can also be located by these tests. In fact, the steaming ability of each unit is shown according to its salt concentration.

This capacity usually increases or decreases with the increase or decrease in concentrations, assuming again in this connection that the boilers are tight and are operating at the same rating and same length of time.

When diligently applied, these tests of the blowdown water make it possible to operate boilers better by avoiding excessive blowdowns in one case and over-concentrations with their resulting steam contaminations in the other, and to detect the many wastes which are so common in boiler operations. When used intelligently and with the full understanding of their meaning they prove very valuable as guides for directing attention to the faulty units and for improving the boiler efficiencies, all of which is important in keeping operating costs to a minimum. This is again illustrated in Example I. Here No. 4 boiler carries the lowest concentrations of any of the operating units. In that this unit burned about the same amount of coal per hour, operated near the same number of hours and proved tight upon inspection, the much lower concentrations it carried could only be caused by poor firing, leaky baffles or faulty drafts.

Engineers may wonder how it is possible to detect such causes by the daily tests for salt concentrations when there apparently seems to be no connection between the two, but the above illustration shows that there is a very definite connection and it is an interesting fact that quite a few broken baffles have been forecast in this way.

Still another important conclusion to be drawn from these simple daily tests is the uniform manner in which the soda treatments are being distributed to the various boilers. This information is frequently necessary where uneven or irregular additions are causing soda and salt carryovers with the steam, and which too often occurs in the treatment of boiler feedwaters.

A division of the salt concentration for each boiler into the alkalinity reading for the same boiler, and comparison of the quotient of this division with similar quotients for other units in service, pictures the distribution of the treatment very nicely. This way of checking the soda feed can best be illustrated by carrying out these divisions for the first mentioned example, as follows:

EXAMPLE II

Boiler No.	Alkalinity		Salt	M.O. Alkalinity Salt
	Pht.	M.O.		
1	10	13	20.0	0.65
2	30	35	37.2	0.66
3	19	23	39.6	0.57
4	3.1	4.5	8.0	0.56
5	15.0	18.5	49.2	0.38

If the chemicals supplied the boilers are proportioned with the feedwater, the quotients resulting through the division of the methyl orange reading by the salt reading should be nearly equal for all boilers.

In the above example boilers Nos. 1 and 2 received the largest proportionate treatment because this product was greatest for these units. On the other hand, No. 5 boiler received the smallest proportion as the product here was only 0.38.

This method for checking chemical distributions is reasonably accurate where the correct conditioning of the feedwaters is maintained at all times and boilers carry no sulphate deposits. If solid sulphates exist over the water surfaces and in turn influence these



factors, they can be detected in two ways: First, by comparing the salt to sulphate relations in the feedwater with similar relations in the blowdown water (if no such sulphates are present these two ratios remain nearly the same); second, by adding enough soda ash to the water within a boiler to give an M.O. alkalinity approximating 250 gr and then banking the boiler or boilers, keeping the steam pressure at less than 5 lb. Follow this by periodic testing of the boiler concentrates for M.O. alkalinity. If solid sulphates are present the M.O. reading decreases in proportion to their weight and the ease with which they are disintegrated. If no sulphates are present the high M.O. alkalinity of 250 gr will remain about the same.

Furthermore, by testing representative samples collected from different sections of the same boiler it is possible to detect undue restrictions in the circulating tubes. Where depositions in these tubes take place in any quantities the difference in the salt-test readings increases, the degree or extent of this, depending upon the extent of the restrictions.

Because of these possibilities it is advisable to find just what this difference is with clean boilers and then make occasional tests to check these differences. It is just another means of foretelling troublesome priming conditions which invariably follow a plugged condition of the circulating tubes. Outside of the uses mentioned the boiler alkalinity and salt readings have no other value when employed alone.

By supplementing these salt tests of the boiler concentrates with similar tests of the feedwater it is possible to determine the *number of times the feedwater is concentrated to one unit volume in each boiler*. This application is probably best understood by assuming that the salt in the feedwater supplying the boilers given under Example II is 1.5 gr. The number of times the feedwater concentrates in each of these boilers therefore is as follows:

EXAMPLE III

Boiler No.	Salt Concentration	Volume before Steaming	Actual Net Volume Concentrations
1	(20-1.5)	minus 1	equals 12
2	(37.2-1.5)	" 1	" 24
3	(39.6-1.5)	" 1	" 25
4	(8.0-1.5)	" 1	" 2 1/2
5	(49.2-1.5)	" 1	" 32

As the salt reading in the feedwater always represents the measure of a volume of this water in the feed, the salt reading for the concentrate must therefore represent a measure of the number of these volumes of feedwater that concentrate before waste of any kind takes place from a boiler. In that the first volume is used to fill the boiler it does not enter into these concentrations and must, under the circumstances, be deducted before the true or actual volume concentrations can be determined.

As the fourth column under Example III carries this deduction it represents the true measure of the number of volumes that are actually boiled down. Knowing this, the total percentage of water waste in the generation of steam is obtained by dividing into one the net or total volumes concentrated and given in column 4 and multiplying by 100, which is the per cent it is required to waste. The results of this follow.

These same salt readings for the boiler feed and blowdown water will also give the boiler ratings and evapora-

tion per pound of fuel. The procedure for this is to first empty the boiler to be tested; then wash thoroughly with fresh water, after which blank the blowdown and fill to the bottom of the gage glass with fresh water. If at all possible, measure this initial volume, otherwise calculate the quantity of water from the size of tubes and drums and any other water spaces within the boiler being tested.

EXAMPLE IV

Boiler No.	Volume Wasted	Actual Net Volume Concentration	Water Waste
1	1	divided by 12	8.3%
2	1	" " 24	4.2%
3	1	" " 25	4.0%
4	1	" " 2 1/2	40.0%
5	1	" " 32	3.1%

Next, determine the salt content of the water within the boiler just before the boiler goes on the line. Draw the sample in this case preferably from the water column after blowing down thoroughly. Place a marker on the gage glass showing the exact water level at this same time. Then start taking water column samples each hour over a 24-hr test period. Also, take a second sample, preferably of bleeder type (continuous), from the feedwater line between the feed pump and boilers over the same 24-hr period. If this is not possible, collect snap samples each hour from any handy connection on the pump discharge. All samples collected during the test should be placed in clean bottles and corked tightly. The time and location of each sampling should also be plainly marked on each bottle. About half an hour before the time for completing the test, start to regulate the feed so the water in the gage glass approximates the marked level at the start of the test. As there is a tendency in some boilers for unequal salt concentrations in different sections, it is advisable to discontinue feeding at least five minutes before the last column sample is drawn. This will allow for more uniform salt distributions and a more representative sampling.

After all the samples have been drawn the feedwater sample is composited and a pint sample taken, if this is a catch sample; otherwise, if a bleeder sample, a pint is taken from the receptacle set up for this purpose. Follow this by tests of feedwater sample and last column sample for salt. Next, subtract the salt in the sample of feedwater from the salt in the column sample and divide the difference by the salt contained in the feedwater. The result of this, times the pounds of water in the boiler at the steaming level, equals the weight of water evaporated over the 24-hr test period. The procedure for this is more clearly illustrated in the following example:

EXAMPLE V

Assume,  
 Salt in the feedwater—1.5 gr per gal  
 Salt in boiler at start of test—1.5 gr per gal  
 Salt in boiler after 24-hr steaming—24.0 gr per gal  
 Rated boiler horsepower—450  
 Pounds of water in boiler at steaming level—37,500 lb  
 Then,  $\frac{(24-1.5) \times 37,500}{1.5} = 562,500$  lb, total evaporation

This is equal to 703 hp, which, divided by 450 hp equals 156 per cent rating. If it is further assumed that the coal consumption over the 24-hr test period was 62,500 lb, then the water evaporated per pound of fuel would be  $562,500 \div 62,500$ , or 9 lb.

In the above connection, while only the final column sampling has been used for computing the rating and

evaporations, the individual hourly test readings also have a valuable application in that the boiler output for each hour over the 24 hr can be approximated in the same way. In further consideration of this method for determining the boiler efficiency, etc., the question may be raised as to the effect a blanked blowdown may have on foaming and priming. Where a boiler is first filled with fresh water this is negligible, even under high ratings.

In all cases where boilers are tested for both ratings and evaporations and also in the every day practice of generating steam, it is desirable to know the waste of water from the boiler or boilers through carryovers.

We again have an easy and accurate method through tests of representative samples of condensed steam for salt and division of this by the salt contained in equally representative samples of blowdown water. The following test results under Example VI will make this clear.

EXAMPLE VI

Boiler No.	Salt in Blowdown, grains	Salt in Feedwater, grains	Salt in Condensed Steam, grains
1	20.0	1.5	0.4
2	37.2	1.5	0.4
3	39.6	1.5	0.4
4	8.0	1.5	0.4
5	49.2	1.5	0.4
Average	31	1.5	0.4

Then, 0.4 divided by 31 equals 1.3 per cent, which is the waste through carryovers. By deducting this finding from the total boiler waste, as it is divulged through tests of the feed and blowdown water, a definite measure of the waste through blowdowns is obtained. This application is made clearer by referring again to Example VI. Here the average salt in the blowdown of 31 gr, when compared with the 1.5 gr salt in the feed, gives the total water waste at 4.8 per cent. As this same example shows the waste through carryovers to be 1.3 per cent and this is included in the total of 4.8 per cent, the actual waste through boiler blowdown in this case is  $4.8 - 1.3$ , or 3.5 per cent. While the results here are for the individual boiler the average plant carryovers can be determined by dividing the average salt for all boilers into the average salt contained in a representative sample of condensed steam collected from a main steam header.

In the chemical conditioning of boiler feedwater the necessity of knowing the percentage of raw water, makeup water, and condensate return is a further vital requirement if the successful control of this is to be accomplished. The salt content in the raw water divided into the salt in the feedwater gives this accurately when the samples tested are again representative of the whole. As for example:

Assume the salt in the raw water to be 5.0 gr, and similar constituent in the feedwater to be 1.5 gr. The percentage of makeup would therefore be  $1.5 \div 5.0$ , or 30 per cent. As the total feed is 100 per cent and makeup is 30 per cent, the difference,  $100 - 30$ , or 70 per cent, represents the condensate return.

There are other uses to which the tests can be applied but as those of greatest value to the power plant engineer have been described further discussions in this connection are unimportant. Outside of some of the sectional-header horizontal type boilers, principally those with two or three drums, these other uses of the simple boiler tests will prove accurate and valuable in

detecting and controlling inefficient practices in the operation of steam boilers. This is not simply a statement, as these values can be proved at any time where standard solutions are employed in testing representative samples of feed and blowdown water and condensate.

The correct interpretation of complete mineral analyses has even more advantages than the daily tests in both the control work and for the detection of inefficient operating conditions. A discussion of this at some later date should prove of special interest to the engineer.

### Carl Stripe Joins Combustion Engineering Company, Inc.

Carl Stripe, for the past two years Assistant to the Vice President of The Davis Coal and Coke Company, has joined the sales organization of Combustion Engineering Company, Inc. He will be in charge of industrial stoker sales under the direction of H. S. Colby, General Sales Manager, and will give particular attention to the unit which has been developed to afford small industrial and heating plants many of the mechanical and economic advantages possessed by larger stoker installations. Mr. Stripe has long been identified with the steam-plant field especially in the application of stokers and the adaptation of particular coals to stoker firing. Prior to his connection with The Davis Coal and Coke Company he was for a number of years successively sales engineer, district sales manager and publicity manager of Combustion Engineering Corporation.

**Engineering Index** is appealing to industry operating in technical fields for a working capital fund of approximately \$160,000 with which to continue the service and spread its use throughout the engineering offices, libraries and colleges of the country, over a five-year period after which it is estimated that it will be self-supporting. About a year ago responsibility for the service was given up by the American Society of Mechanical Engineers and in June the Index was incorporated as a non-profit organization in its own right under the supervision of a board of directors consisting of five prominent engineers. About two thousand publications are reviewed regularly by the Index. Plans for the endowment campaign call for a National Campaign Committee and local committees for each of twelve industrial centers.

**Sir Alfred Ewing** internationally known for his work on thermodynamics, his classical treatise on the steam engine and his scientific investigations on strength of materials, died at Cambridge, England, on January 7 at the age of 79.

**W. J. McDonough** has been appointed Sales Manager of Northern Equipment Company, Erie, Pa. He has been associated with the Copes organization since 1922.



# STEAM ENGINEERING ABROAD

As reported in the foreign technical press

## Flue Gas Washing at Battersea

The very elaborate system of flue gas washing employed at the Battersea Station of the London Power Company has been fully described in the technical press but little information appears to have been given out concerning its performance. An item in *The Fuel Economist* (London) of January quotes from a report of the Government chemist to the effect that the gases discharged to the atmosphere are reduced to 0.03 gr of sulphur as sulphurous anhydride per cubic foot. Furthermore, the Port of London Authority, which has laid down rules for the condition of the water passed back into the Thames after being used for washing the gas, finds that this is well within the limits imposed, namely, that the Thames water shall not be rendered acid nor contain more than 14 gr in 100 gal of deoxygenating matter (including sulphite) above which it had originally.

## High and Medium Pressure Boilers Combine to Supply Power and District Heating

An interesting installation of high and medium pressure boilers for power and central heating at the Federal Technical University at Zurich, Switzerland is described in the *Sulzer Technical Review*. It consists of a 1400-lb Sulzer single-circuit boiler supplying steam to a high-pressure turbine which exhausts to the 500-lb system which is also supplied direct by a Sulzer two-drum boiler. The 500-lb system supplies both a condensing turbine with two-point bleeding at 145 lb for district heating and 15 lb for heating water, and a back pressure bleeder turbine also feeding into the 145 and the 15 lb lines. The condensing turbine is of the cross-compound type having a single generator with the low-pressure element driving the generator direct through a coupling and the high-pressure element geared to the generator in such a way that either turbine may be shut down without taking the generator out of service.

## North Wilford Station Extension

Typifying British practice in the present program of central station extensions is the addition to the North Wilford Station at Nottingham, described in *The Steam Engineer* (London) of January 1935. As in many other British stations, both new and extensions, medium size boilers, moderate pressure, higher steam temperature,

solid forged drums, both air heaters and economizers and flue-gas washing are adopted. The North Wilford Station extension will consist of four Combustion steam generators of 200,000 lb per hr maximum continuous capacity, producing steam at 625 lb pressure and 800-850 F. Each boiler will be served by two unit mills with direct firing of pulverized coal. The air heater is placed after the economizer and will raise the temperature of the incoming air to 452 F, and the flue gases after passing through the washer will discharge to a 250-ft stack constructed of copper bearing steel to resist corrosion.

## Low-Temperature Carbonization Increases in England

The Secretary for the Mines Department (Great Britain) reports that during 1934 there were in commercial operation in England nine low-temperature plants which handled a total of 318,000 tons of coal, an increase of 42 per cent over the preceding year. Two additional plants of 300,000 tons combined capacity and employing the Coalite process are about to be erected. The average yield of the existing plants, from one ton of good grade washed bituminous coal is stated to be 14 cwt of smokeless fuel, 18 gal of crude coal oil, 3 gal of gasoline, 30 therms of gas and 4 lb of sulphate of ammonia.

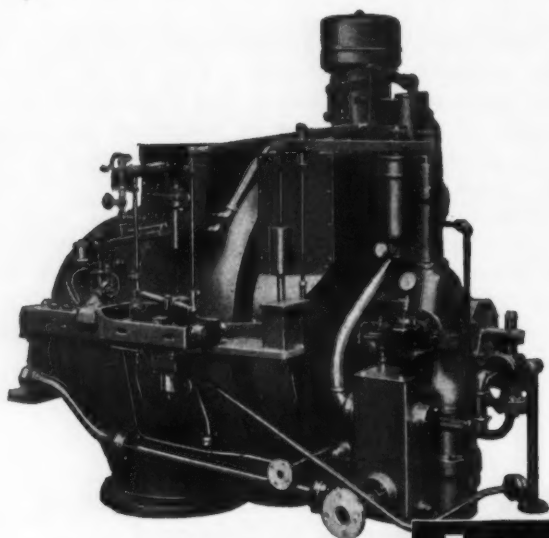
## New Marine Turbine Unit Employs Compact Arrangement

The Parsons Marine Steam Turbine Company, according to *Engineering* (London) of Dec. 28, has brought out a simplex geared steam turbine unit for marine service which combines compactness, simplicity and low first cost comparable with that of a reciprocating engine. The set consists of a high-pressure and a low-pressure turbine in series, both working on the same pinion for sizes up to 2000 hp and on separate pinions for larger powers. The turbine speed of 4000 rpm is thus reduced to a shaft speed of 80 rpm. The turbine, gear box, condenser and auxiliary unit are all mounted on the same bedplate. The last named is normally driven by a chain from the main shaft through a clutch, but for starting or maneuvering a small reciprocating engine is provided to drive the auxiliary set through a clutch. When running normally at sea the engine is cut out and advantage taken of the economy of drive from the main unit.

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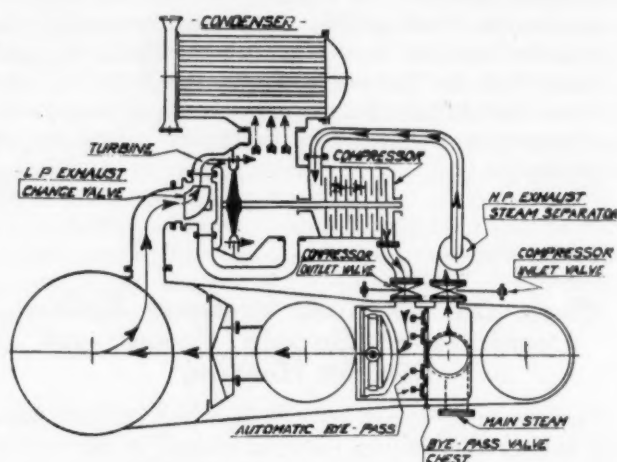
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## Turbine-Compressor and Reciprocating Engine Combination

A combination for increasing both the power and the efficiency of a marine power plant is represented by the Rowan-Gotaverken exhaust turbine system, described in the December issue of *Engineering and Boiler House Review* (London). This arrangement consists of an exhaust steam turbine installed between the low-pressure cylinder of a reciprocating engine and the condenser. This turbine drives a steam compressor which takes the exhaust from the high-pressure cylinder (or the intermediate pressure cylinder if desired) and, after raising the steam to a higher pressure and temperature, returns it to the receiver of the following cylinder. The accompanying diagram shows the arrangement with the arrows indicating the path of the steam. Automatic by-pass valves are provided which pass the steam direct to the intermediate cylinder when the compressor is not working. The compressor and the turbine are mechanically independent of the engine and do not require to be cut out when going astern or maneuvering.



The steam circuit with the turbo compressor in use.  
The automatic by-pass valves are shut.

The energy developed by the turbine is conveyed to the reciprocating engine cylinders by the steam itself, through the work done on it by the compressor and the effect is to raise the thermal efficiency or to obtain an increased output with the same fuel consumption.

This equipment has now been installed on seven vessels one of which was recently tested by Dr. A. L. Mellanby of the Royal West of Scotland Technical College. These showed a net saving in total heat per horsepower per hour of over 18 per cent when running on superheated steam and 20.7 per cent when using saturated steam.

## British Admiralty Orders Velox Boiler

*The Engineer* (London) of Jan. 11 states that the British Admiralty has placed an order for a Velox steam generator which will be used for experimental purposes, the small space requirements and weight and high combustion rates of this type of boiler being especially adapted to naval work. The unit is to be built in England by the British licensee of Brown Boveri & Co.



## Russian Power Plants

Some interesting sidelights on power plant developments in Russia are contained in a paper by Allan Monkhouse before the January 1935 meeting of the Institution of Electrical Engineers, and reported in *Engineering*.

In the past ten years fifty-six large power stations have been built and over eight thousand miles of high-tension (110,000 to 220,000 volts) transmission lines undertaken. The "Glavenergo," a divisional government commission having supervision of 65 per cent of the generating plants in U.S.S.R., representing about three million kilowatts capacity, reports an average fuel consumption, covering 81 plants, of 1.55 lb per kilowatt-hour as compared with 1.76 for 1932.

For economic and strategic reasons it has been considered advisable to make the northern industrial areas, including Leningrad and Moscow, independent of the bituminous and anthracite coal fields of the Ukraine and the oil fields of the South, by utilizing the very extensive peat deposits of the Northern areas. Hence about 30 per cent of the boiler plants under supervision of the Glavenergo burn peat. Sixteen peat-burning stations with a total capacity of 903,000 kw are now in operation and one of 150,000 kw is under construction. By 1937 the total capacity of peat-burning stations will have reached 3,028,000 kw.

Two methods for burning the peat are in use. One employs a chain-grate stoker, arches and preheated air which is passed up through the peat as it descends in the chute from the hopper. The second method involves the burning of milled peat in suspension with the aid of preheated air. Experience has shown that the most satisfactory results are had when the peat has been partially dried to contain about 32 per cent moisture.

The 186,000 kw Kashira Station supplying Moscow burns brown coal and in the Ukraine five stations with an ultimate capacity of 691,000 kw have been built to burn pulverized anthracite waste.

## 160,000 Hp Turbine-Electric Drive for New French Liner

Comparable to a fair sized central station will be the power plant of the new French liner *Normandie* which is now being fitted out at one of the French shipyards preparatory to being placed in trans-Atlantic service, between Havre and New York, early this summer.

Turbine-electric drive, aggregating 160,000 hp for the main units, will be employed. This is the first turbine-electric drive of such magnitude to be employed in commercial ships (the airplane carriers *Lexington* and *Saratoga* each have 180,000 hp). There will be four 40,000-hp turbine-generators supplying four three-phase, 5,000-volt motors one coupled direct to each of the four propellers. Steam will be supplied by twenty-nine oil-fired boilers at a pressure of 400 lb per sq in. and 662 F total temperature.

In addition to the main turbine-generators there will be six auxiliary units, aggregating approximately 13,000 kw which will supply electricity for lighting and cooking and auxiliary power for ventilating, air conditioning and numerous other services.

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Downdraft Furnaces: The January issue was devoted to handling the fire on the lower grate of downdraft furnaces. To fire the upper grate, carry the thickest fuel bed with the lowest draft between the grates that will carry the load and burn the fuel properly. Keep a thin covering of green coal over the top surface of the fuel bed by firing about every 3 or 4 minutes. This method lowers the temperature in the firing aisle and gives a continuous distillation of the volatile gases thru the incandescent bed of fuel. In removing the clinkers, exercise care to deposit as little fuel as possible on the lower grate. Cover all holes in the fire quickly and carry a heavier bed of fuel in the two back corners of the grate. Check your furnace efficiency with the new Ellison Portable Gas Analyzer.

Downdraft Furnace Efficiency Lesson V in April Issue

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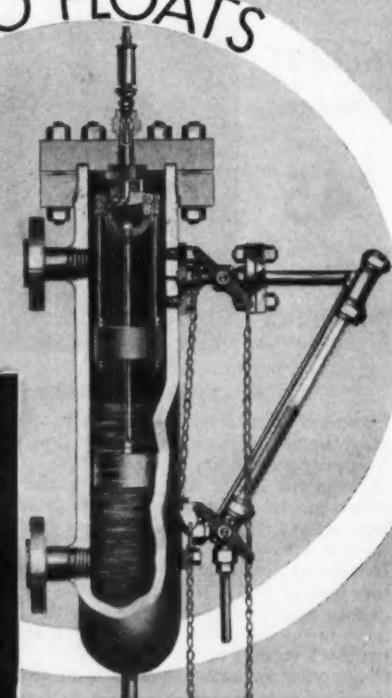
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## Density of a Humid Atmosphere

By C. Harold Berry

Professor of Mechanical Engineering  
 The Harvard Engineering School

Two equations have been proposed for the computation of the mixture density of a humid atmosphere, that is, the weight of air plus water vapor per cubic foot. One, proposed by the present author (1), is an approximation good to three significant digits,

$$d_m = \frac{B - 0.38p_v}{RT_d} \quad (1)$$

where  $B$  = barometric pressure and  $p_v$  = actual vapor pressure (both of these pressures must be in the same units, which may be any whatever);  $T_d$  = dry bulb temperature, F absolute;  $R$  = gas constant for air = 0.370 for pressures in lb per sq in. = 0.754 for pressures in inches of mercury at 32 F; and  $d_m$  = mixture density in pounds of air-plus-vapor per cubic foot.

The actual vapor pressure, it has been suggested, may be found with adequate accuracy by Apjohn's equation (2) (modified),

$$p_v = p_w - \frac{B(t_d - t_w)}{30 \cdot 90} \quad (2)$$

where  $t_d$  and  $t_w$  are, respectively, the dry-bulb and wet-bulb temperatures, F; and  $p_w$  = pressure of saturated vapor at  $t_w$  (from steam tables).

More recently, Prof. Newton C. Ebaugh has proposed (3) another approximate equation,

$$d_m = \frac{B - 0.378 p_w}{RT_d} \quad (3)$$

In Professor Ebaugh's paper, this equation is given in a slightly different form, in that he has used a specific value of the gas constant  $R$  and thus has obtained an equation in which the pressures must be expressed in inches of mercury, which may sometimes be inconvenient. Moreover, he has reduced his denominator to the form  $RT_d = (460R + Rt_d)$ . It seems to the writer that this form is less convenient for computation, since it introduces an addition of complicated numbers, whereas the form of equation (1) above involves the addition of 460 and  $t_d$ , which can usually be done mentally so that the resulting  $T_d$  can be written down directly.

In a more serious particular, the writer would like to take exception to Professor Ebaugh's suggested equation. He has given all of his numerical values to too many significant digits. In the numerator, the constant factor 0.378 implies that the value of  $p_w$  is to be determined to three digits. This demands that the wet-bulb temperature be measured to one-tenth of one degree, as will be seen from an inspection of the steam table. Ordinarily such precision is not approached. If this pressure were known to three digits, the numerator, involving  $B$ , would present five digits. In the denominator, Professor Ebaugh carries his constants to four digits, and this implies that the dry-bulb temperature has been measured to one-tenth of one degree, which likewise is rarely accomplished or even attempted.

Moreover, in setting up his equation, Professor Ebaugh discards as negligible the difference between unity and the factor  $[1 + 0.00014(t_d - t_w)]$ . When the wet-bulb depression is zero, this factor is obviously equal to unity, and equations (1) and (3) become identical. But when the wet-bulb depression is not zero the error may be considerable. For example, when the depression is 10 deg, the difference becomes 0.0014, which is 1 part in 700. When the depression is 20 deg, the difference is 2 parts in 700. Inasmuch as the mixture density will often come out in the neighborhood of 0.0750, this means that the error resulting from the use of Professor Ebaugh's approximation will often be of the order of one or two units in the third digit. This certainly does not justify carrying the computation to four digits, and, further, the writer believes that it does not give sufficient accuracy of result for ordinary engineering applications.

As a check on both equations, the writer has assumed a few values of  $t_d$ ,  $t_w$  and  $B$ , and for each of them has computed the mixture density in three ways. First, he has computed  $p_v$  by means of Ferrel's psychrometric equation, and has computed densities to five digits, by means of a computing machine, using the best attainable values of all constants. ( $T = t + 459.63$ ;  $R = 0.37042$ ; vapor densities from the steam tables, corrected



from saturation at  $t_d$  by the pressure ratio and from saturation at the dew point by the temperature ratio). These values he calls the "exact" values, with apologies for the rather absurd array of significant digits. Second, he has computed densities by means of equations (1) and (2), by slide-rule. Third, he has computed densities by means of equation (3) by slide-rule. The accompanying table presents the results, just as they came out, with no effort to recompute the slide-rule results that appear to be out of line. It appears that equation (1) gave 11 results that

#### COMPUTED VALUES OF MIXTURE DENSITY

Results are designated as "exact" (see text for method), "Apjohn" for equations (1) and (2), and "Ebaugh" for equation (3).

$t_d$	$t_w$	$B = 30$ inches of mercury			$B = 20$ inches of mercury		
		Exact	Apjohn	Ebaugh	Exact	Apjohn	Ebaugh
100	100	.069357	.0693	.0693	.045663	.0456	.0456
	90	.069914	.0699	.0697	.046186	.0461	.0461
	80	.070363	.0703	.0701	.046602	.0466	.0464
	70	.070725	.0707	.0704	.046920	.0469	.0467
80	80	.072759	.0727	.0727	.048188	.0481	.0482
	70	.073136	.0731	.0730	.048529	.0484	.0484
	60	.073441	.0734	.0732	.048800	.0487	.0486
	50	.073690	.0737	.0733	.049015	.0489	.0488
60	60	.076052	.0760	.0760	.050534	.0505	.0505
	50	.076312	.0763	.0761	.050758	.0507	.0506
	40	.076528	.0765	.0762	.050940	.0509	.0507
	35	.079370	.0793	.0793	.052830	.0527	.0528
40	35	.079470	.0794	.0793	.052911	.0528	.0528

agree with the "exact" values (to the third digit), and fifteen results that were small by one unit in the third digit. Equation (3), on the other hand, gave three results that agreed in the third digit, nine that were low by one unit, ten that were low by two units, three that were low by three units and one that was low by four units.

Professor Ebaugh's equation and chart are a little easier to use than equation (1), for the latter demands a preliminary computation of  $p_s$  by equation (2). On the other hand, equation (3) does not give a result that is dependable in the third digit. That is, it does not give an accuracy that is compatible with a reading of the dry-bulb temperature to the nearest degree. While there is much work in which an approximate result is wholly adequate, there are many instances in which errors of the magnitude cited would not be permissible. The writer wishes to cast no aspersions on Professor Ebaugh's suggestion, but does think it desirable to point out the attendant possibility of error, so that the user of the chart may know when it may be used.

(1) A Simple Method for Humidity Computations, COMBUSTION (October 1934).

(2) A Comparison of Psychrometric Equations, COMBUSTION (Sept. 1934).

(3) Air Density Formula and Chart, COMBUSTION (Dec. 1934).

### A Reply by Professor Ebaugh

Professor Berry's discussion agrees in the main with the statements made in my discussion which appeared in the December issue of COMBUSTION. It was stated that the writer's discussion was based on Professor Berry's August and September articles which are considered to be very able and interesting. My contribution was sent in before the October article was received, otherwise it would have been possible to materially shorten the discussion because his equation (3) and my equation (1) are practically identical except as to units.

It still appears that equation (3) of my discussion which used inches of mercury for pressure and degrees Fahrenheit for temperature is as convenient as any since these are the units usually employed when making the primary observations.

It was stated in my discussion that equation (1) was the more exact relation and that equation (3) was a practical relation which is suitable for the usual wet bulb depressions found with atmospheric air, at least up to a 20 deg depression. For a 20 deg depression, as Professor Berry correctly points out, the error in the density is only 1 part in 350 which is less than  $\frac{1}{4}$  of 1 per cent. The error is still less for lower wet bulb depressions. This accuracy is acceptable for many engineering applications. Three significant figures are all that should be used with equation (3) and the density chart presented.

The writer pointed out the possibility of such small errors in the comments directly below the chart in the December COMBUSTION and any thoughtful user should know its limitations. However, Professor Berry's interest in assuring the correct use of this chart is appreciated by the author.



## COME A-RUNNING !



Low water!

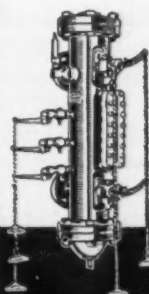
Never mind about who should have seen it coming by the water gage. This is a busy power plant.

But the Reliance Alarm is never busy with anything except watching that boiler water level.

The whistle blew—instantly. The alert buoyant unsinkable float saw to that—more than 4 times as quickly as any non-float column can, when quickness counts. The floats are guaranteed unsinkable in their service—did you know that?

Specify Reliance for hair-trigger alarms that have not failed in an emergency in 51 years.

The Reliance Gauge Column Co.  
5942 Carnegie Ave.,  
Cleveland, Ohio



**Reliance**  
SAFETY WATER COLUMNS

More than 5,000 boiler plants of all types and sizes will testify to the outstanding performance of "Diamond" products:

DIAMOND "AUTOMATIC VALVED" SOOT BLOWERS

DIAMOND "LOOSE WINDOW" HIGH PRESSURE GAUGES

DIAMOND BI-COLOR WATER GAUGES

DIAMOND HIGH PRESSURE WATER COLUMNS

DIAMOND DESLAGGERS

DIAMOND AUTOMATIC AIR PUFF SOOT BLOWERS

Diamond Power Specialty Corporation  
DETROIT, MICHIGAN

Diamond Specialty Limited  
WINDSOR, ONTARIO

# REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from  
Combustion Publishing Company, Inc., 200 Madison Ave., New York

## Power Plant Testing (Fourth Edition)

By James A. Moyer

For a number of years this book has been widely accepted as a reference and guide in power plant testing. Since the appearance of the third edition in 1926 advances in power plant practice have been such as to warrant certain refinements in testing, in accordance with standards recommended by the engineering societies. This is particularly true of temperature and pressure measurements and in certain phases of steam turbine work.

The present edition, while retaining the fundamental material contained in the earlier editions, has been partly rewritten and amplified to include the new codes and testing methods as recommended by the Power Test Codes Committee of the A.S.M.E. and by other societies. A large number of engineers and teachers have contributed toward this revision.

The scope of this book, as indicated by a partial list of chapter headings, is as follows: Measurement of Pressure; Measurement of Temperature; Determination of the Moisture in Steam; Measurement of Areas; Measurement of Power—Dynamometers; Flow of Fluids; Flue-Gas Analysis; Testing of Boilers and Other Steam-Generating Units; Testing Steam Turbines and Turbogenerators; Tests of Complete Steam Power Plants—Coal Fired; Gas and Oil-Engine Producer Testing; Testing of Ventilating Fans or Blowers and Air Compressors; Testing of Lubricants; Testing of Governors.

The book may be regarded both as a reference for teaching and for practical testing.

*Power Plant Testing* contains 614 pages, 6 × 9, 335 illustrations, numerous charts and tables, and a very comprehensive index. The appended outline of suggested tests should prove most useful. Price \$5.00.

## Book of A.S.T.M. Tentative Standards

1934 Edition

This publication, issued each year by the American Society for Testing Materials, is the only volume containing all of the A.S.T.M. tentative specifications, methods of test and definitions of terms covering engineering materials and the allied testing field. These tentative standards, issued as *proposed* standards, embodying the latest thoughts and practices, find important applications throughout industry.

New tentative specifications published for the first time in 1934 cover the following ferrous and non-ferrous materials: electric-fusion-welded steel pipe for high-temperature and high-pressure service; alloy-steel castings for valves, flanges and fittings for service at temperatures from 750 to 1100 F; and for the same temperature range, seamless alloy-steel pipe; sheet-copper silicon alloy; copper-silicon alloy rods, bars and shapes,

and plates and sheets; also, magnesium-base alloy ingot for remelting, and magnesium-base alloy die castings.

In the cementitious, ceramic and masonry field new standards cover portland cement mortars (compressive strength test), sodium silicate for curing concrete, ground fire clay, refractories for the construction of incinerators and structural clay tile (sampling and testing).

Other specifications which have been included for the first time cover such important materials as fuel oils; various types of emulsified asphalts; woolen and worsted yarns; titanium barium pigment; titanium calcium pigment; zinc sulfide and high-zinc sulfide lithopone; insulated wire and cable (class A, 30 per cent Hevea rubber compound); vulcanized rubber (test for compression set); creosote and creosote coal-tar solution.

In addition to the 236 A.S.T.M. tentative standards, the 1934 *Book of Tentative Standards* includes all proposed revisions of standards, which are published to elicit criticism before final adoption.

Extensive revisions have been incorporated in the requirements for cold-rolled strip steel; black and hot-dipped zinc-coated welded and seamless steel pipe for ordinary uses; reinforced and non-reinforced concrete sewer pipe; timber piles; friction tape for general electrical use; and grease wool and allied fibers.

To facilitate the use of the book a complete subject index has been included, listing items under the materials and subjects to which they apply; and two tables of contents are given, one listing the standards in the order they appear (grouped under general subjects) and the second listing the items in numeric sequence of serial designations.

The book contains 1257 pages, size 9 × 6. Price \$7.00 heavy paper cover; \$8.00 cloth binding.

## Practical Everyday Chemistry

By H. Bennett

Despite the title, this is not a simplified book on chemistry as one usually regards the subject with its numerous chemical formulas, reactions, etc. Instead, it is based on the fact that most everything we use in daily life is either a chemical mixture or involves some form of chemistry in its process of manufacture. These numerous products are often effectively disguised under trade names, and their composition and methods of manufacture hold general interest for those of an inquiring mind. The chapter on materials of construction should, in particular, provide a handy reference for many engineers.

Among the other subjects discussed in this book are the following: adhesives; agricultural and garden specialties; coatings, protective and decorative; food products, beverages and flavors; inks, carbon paper, crayons, etc.; lubricants, oils, etc.; paper; photography; plating; abrasives, etc.; rubber, plastics, waxes, etc.; textiles and fibers.

This book contains 303 pages, size 5½ × 8. Price \$2.00.



# NEW EQUIPMENT

of interest to steam plant engineers

## Elliott Marine-Type Deaerating Heater

The Elliott Company, Jeannette, Pa., has developed a special type deaerating heater for use in marine service. This heater gives the same performance on shipboard as is obtained in heating feed-water by direct contact in conventional stationary type deaerating heaters. The deaerating element is of special design and construction and is particularly efficient from the standpoint of allowing intimate contact of water and steam, and uniform distribution of water, regardless of the roll and pitch of the ship. Flexibility of design is employed so that the heaters can be fitted into the space available on shipboard.

The deaerating heater heads are of the non-storage type, made of cast iron to give maximum resistance to corrosion. This was considered of more importance than the disadvantage of the extra weight of a cast iron structure over steel plate. The standard material for the shell and end heads is copper bearing steel or Armco ingot iron, as preferred, for the primary reason of minimum weight. If the importance of greater corrosion resistance is sufficient to offset the disadvantage of added weight, cast iron can be used. Storage tanks are of copper bearing steel or armco ingot iron; the vent condensers of steel plate or cast iron. Water storage tanks may be of the vertical or horizontal type, to meet the specific requirements for installation and the capacity of a storage tank can be provided to meet the storage requirements of each application. Support arrangements are welded to the storage tank for any desired type of mounting.

## Boiler Meter for Industrial Service

To supply the increasing demand of industrial establishments for higher boiler room economy, Bailey Meter Company, Cleveland, O., has developed a new steam flow-air flow boiler meter particularly suited to industrial service. This meter records steam flow from the boiler, air flow supplied for combustion and flue gas temperature—all on one 12-in. uniformly graduated chart. It also indicates steam flow on a porcelain enameled scale and integrates the total steam flow on a six-digit counter which reads like an automobile mileage register.

It is equipped with the new direct-reading Bailey escapement type integrator; an accurate, sensitive air flow mechanism; a sturdy, dust and moisture-proof pressed steel casing suitable for flush front or surface mounting; and a simplified, powerful steam flow mechanism with interchangeable head chambers.

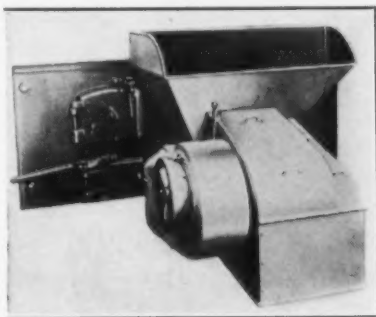
Because of the present-day trend to the use of automatic combustion control in industrial boiler plants, the new Meter has been designed to fit into the Bailey Meter Control System. In this service, it automatically maintains maximum combustion efficiency by regulating air supply or stoker speed. In addition to maintaining combustion efficiency, the system maintains steam pressure and furnace draft at the desired standard.

## Pumping Unit

The Chicago Pump Company has brought out a compact pumping unit in which the pump is of the end-suction type, close-coupled to the motor frame, and the impeller keyed to an extension of the motor shaft. The unit is built in capacities ranging from 100 to 600 g.p.m. for heads up to 189 ft. and is designed for high efficiencies. The impeller is of bronze, as are also the wearing rings and the pump is furnished either with or without a water seal. It is particularly applicable to water supply systems, circulating and cooling systems, as well as handling certain industrial liquids.

## C-E Stoker-Unit, Design S

A new self-contained stoker unit, designated as Type S and intended for small heating and industrial plants having either fire-tube or water-tube boilers, has just been brought out by Combustion Engineering Company, New York. It has a screw conveyor which advances the coal from the hopper to the entrance of the retort and a reciprocating pusher in the retort continues the feeding and provides agitation for the fuel bed. Coal distribution is accomplished by the lateral movement of moving grate bars which alternate with fixed bars.



An integral blower, with inlet damper control, supplies air to the windbox under the stoker. The volume of air is regulated automatically through a control lever to suit the stoker speed. A constant speed motor drives the stoker through an integral variable-speed transmission permitting sixteen rates of coal feed. Coal feed may be cut off by means of a clutch so that the fan may continue to operate for burning out the fuel.

The stoker is designed so as to employ either a center or a side retort, the former being shown in the accompanying view. The small clearances required permit installation, in most cases, with only slight alterations in the setting and the brickwork is seldom disturbed. The stoker body is shipped completely assembled, in a series of sizes, for installation under the boiler.

## Motorized Reducers

In order to meet the growing demand for greater compactness and economy in self-contained enclosed speed reducing units, Link-Belt Company, announces a new line of motorized helical-gear re-

ducers, a feature of which is unusual accessibility of the motor and the high-speed gears.

A standard round-frame motor is secured to the side of the reducer housing by means of an adapter casting which supports the motor shaft in over-size anti-friction bearings close to the pinion. The complete motor, with adapter and motor pinion, may be removed as a unit for inspection or maintenance, without disturbing the alignment; in fact, the motor pinion and gear are removable without disconnecting the driven machine or disturbing the low-speed gears.

The new motorized reducers may be mounted on the floor, ceiling or wall; and are available in double reduction for  $\frac{1}{2}$  to 75 hp in ratios up to  $38\frac{1}{2}$  to 1, and in triple reduction up to 30 hp, in ratios up to 292 to 1. They embody the usual advantages of not requiring a motor base plate or a high-speed shaft coupling, and as the motor forms an integral part of the reducer, the proper alignment of motor shaft is definitely assured at all times.

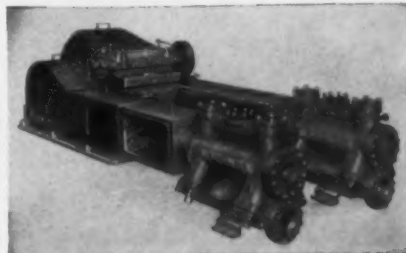
## Temperature-Indicating Meter

High temperatures may materially shorten the life of electrical equipment. Therefore, in order to detect abnormal temperatures in the windings of a-c generators, motors and transformers, a temperature-indicating meter has been brought out by the General Electric Company. Either continuous or occasional readings are possible.

The meter has a two-coil armature, one coil of which is connected in series with the copper detectors embedded in the windings of the machine; the other is in series with an internal resistor, which has practically a zero temperature coefficient. A disturbance of the ratio of current between the two coils causes the needle of the instrument to be deflected. Heating of the detector changes the ratio, which change is indicated on the calibrated scale. The instrument is calibrated in degrees centigrade and may be installed at the machine panel or on the switchboard for remote indication.

## Totally Enclosed Frame Power Pump

Worthington Pump and Machinery Corporation, Harrison, New Jersey, has just announced the completion of a new type of totally enclosed horizontal duplex power pump that has unusual features. This pump, which is of 18 in. stroke, is shown in the accompanying cut. The power end frames are cast en bloc and all power end moving parts are entirely enclosed so as to be dirt-tight and oil-tight. The main pinion shaft and crank pin bearings are of the frictionless double-row roller type. Lubrication under pressure is supplied to all bearings and likewise is sprayed into the inter-mesh of the gears. The machine is self-contained and is supported on the foundations throughout its length.



# EQUIPMENT SALES

## Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census

### Boiler Sales

Orders for 50 water-tube and h.r.t. boilers were placed in December

	Number	Square Feet
December, 1934.....	50	128,903
December, 1933.....	56	166,293
January to December (inclusive, 1934).....	852	2,436,550
Same period, 1933.....	944	2,871,913

NEW ORDERS, BY KIND, PLACED IN DECEMBER, 1933-1934

Kind	December, 1933		December, 1934	
	Number	Square Feet	Number	Square Feet
Stationary:				
Water tube.....	37	143,261	28	108,829
Horizontal return tubular....	19	23,032	22	20,074
	56	166,293	50	128,903

### Mechanical Stoker Sales

Orders for 151 stokers, Class, 4\* totaling 26,349 hp were placed in December by 60 manufacturers

	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
December, 1934.....	121	15,544	30	10,805
December, 1933.....	109	14,617	13	4,225
January to December (inclusive, 1934).....	1,546	195,105	470	185,305
Same period, 1933.....	1,231	154,909	421	151,868

\* Capacity over 300 lb of coal per hr.

### Pulverized Fuel Equipment Sales

Orders for 8 pulverizers with a total capacity of 25,030 lb per hr were placed in December

#### STORAGE SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
December, 1934.....	8	1	1	46,000	4	109,432	1,445,000
December, 1933.....	8	4	4	220,000	4	109,432	1,445,000
January to December (inclusive, 1934).....	8	1	1	46,000	4	109,432	1,445,000
Same period, 1933.....	6	4	2	220,000	4	109,432	1,445,000

#### DIRECT FIRED OR UNIT SYSTEM

	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb coal per hour for contract	Number	Total sq ft steam-generating surface	Total lb steam per hour equivalent
December, 1934.....	8	7	1	25,030	6	42,778	360,000
December, 1933.....	8	4	4	67,500	5	53,200	653,000
January to December (inclusive, 1934).....	90	64	26	527,815	71	454,795	4,532,370
Same period, 1933.....	107	74	33	700,240	81	591,977	5,979,810
					Fire-tube Boilers		
December, 1934.....	..	..	..	..	2	4,000	28,000
December, 1933.....	..	..	..	..	..	..	..
January to December (inclusive, 1934).....	12	3	9	11,765	13	15,486	111,900
Same period, 1933.....	17	3	14	19,450	18	27,610	170,940

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